



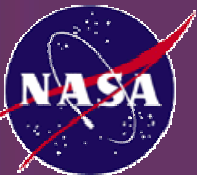
Joint Council on Aging Aircraft/
Joint Group on Pollution Prevention



JCAA/JG-PP Lead-Free Solder Project: Vibration Test

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Boeing Phantom Works
Seattle, WA

IPC APEX
Anaheim, CA
February 5 - 10, 2006



Vibration Testing

31 Test Vehicles

✓ **One “Pathfinder” Test Vehicle**

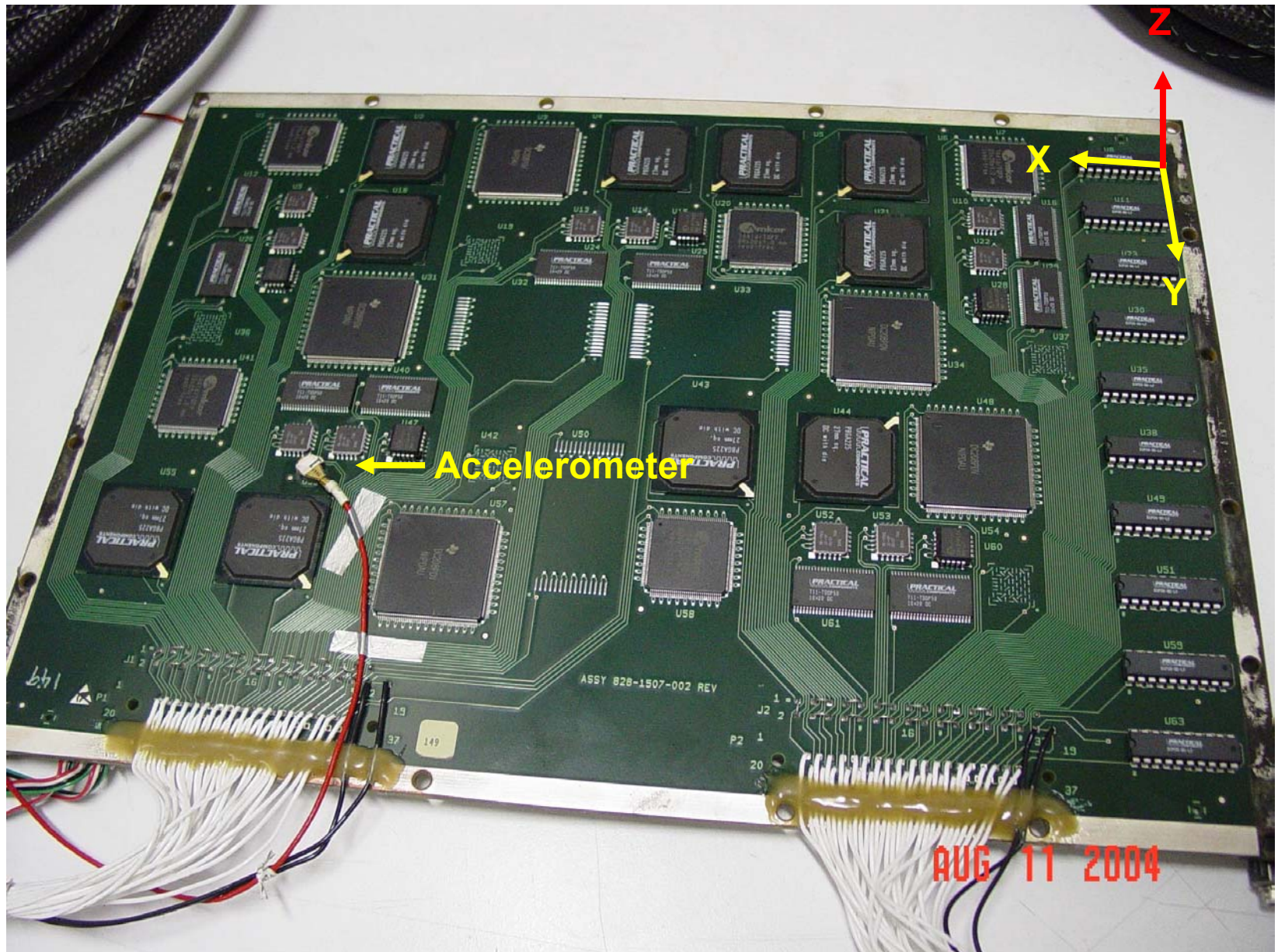
✓ **15 “Manufactured” Test Vehicles**

- 5 – SnPb (reflow/wave)
- 5 – SnAgCu (reflow/wave)
- 5 – SnAgCuBi (reflow), SnCu (wave)

✓ **15 “Reworked” Test Vehicles (assembled with SnPb)**

- 5 – reworked with SnPb
- 5 – reworked with SnAgCu
- 5 – reworked with SnAgCuBi or SnCu (DIP's only)

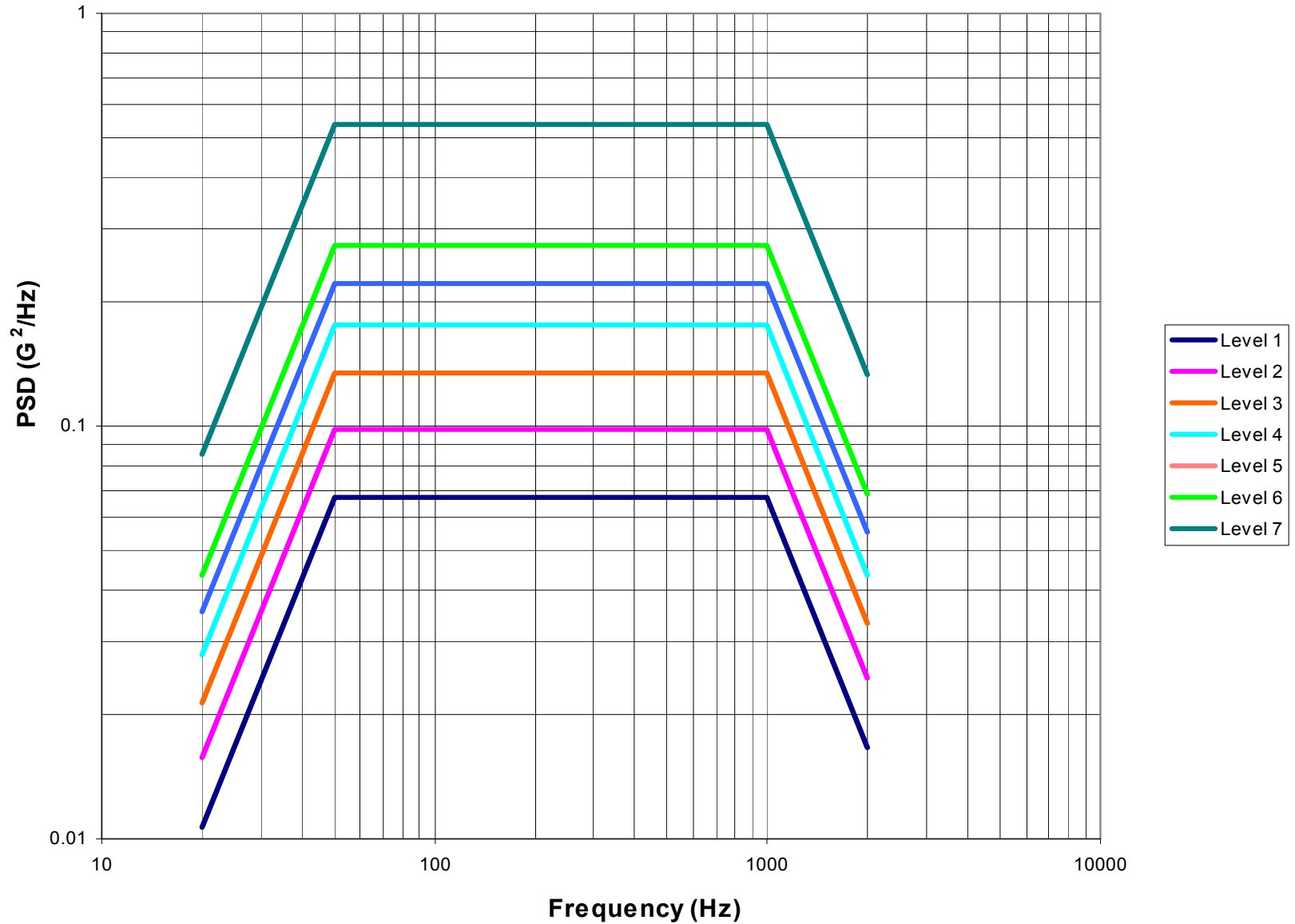
Test Vehicle



Vibration Testing

- Tested in x, y, and z axes (one hour each at 9.9 Grms)
- Then tested in z axis only
 - ➡ Increase Grms level every hour

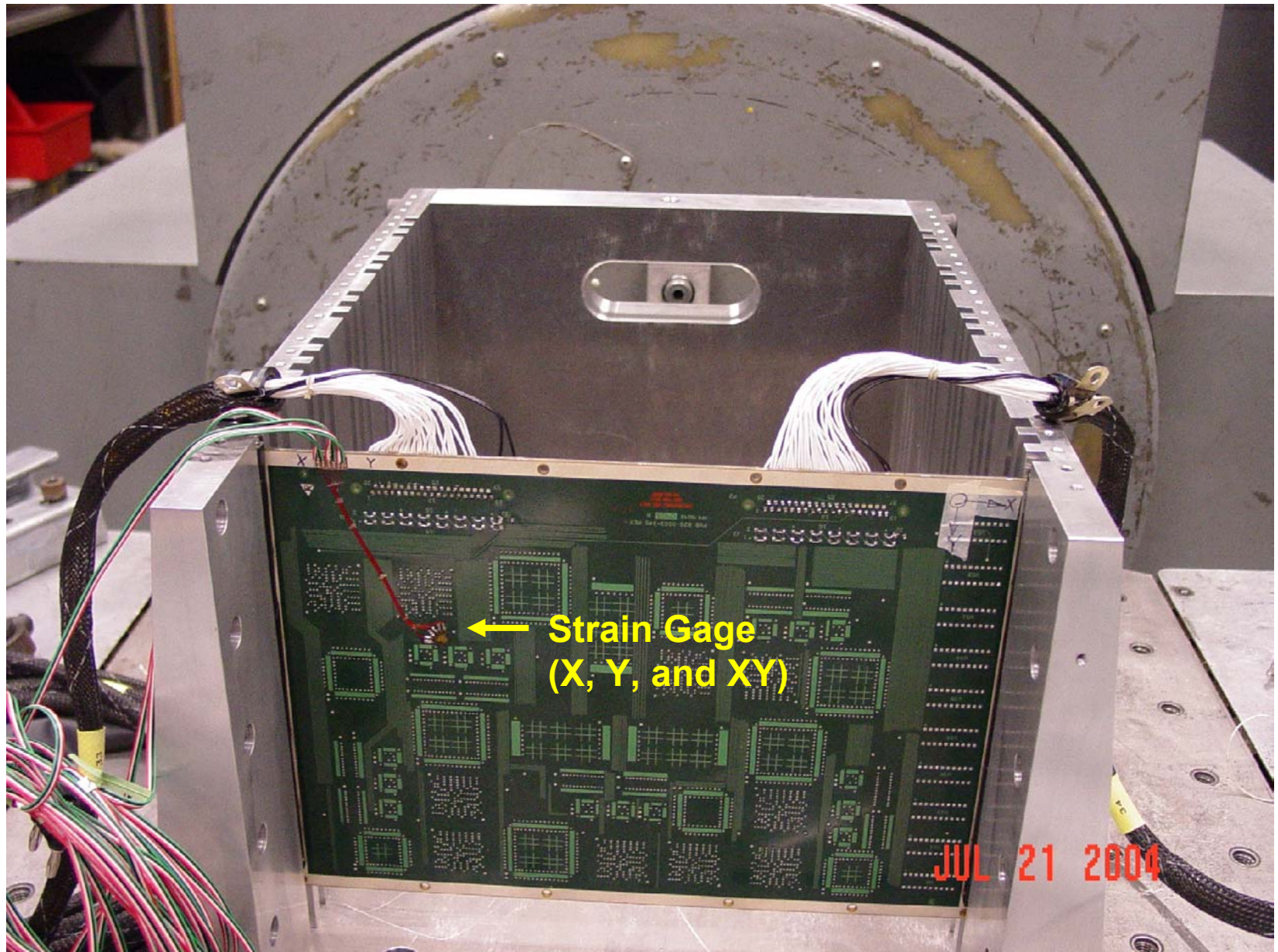
Vibration Test Levels



“Pathfinder” Test Vehicle

- A “pathfinder” test vehicle was used:
 - ✓ To verify that there were no problems with electronic noise, the fixture, or the wires
 - ✓ A modal analysis was done using a laser vibrometer (maps mode shapes; identifies resonances; maps strain field)
 - ✓ A strain gage was also mounted on the “pathfinder” board to collect strain data at each test level

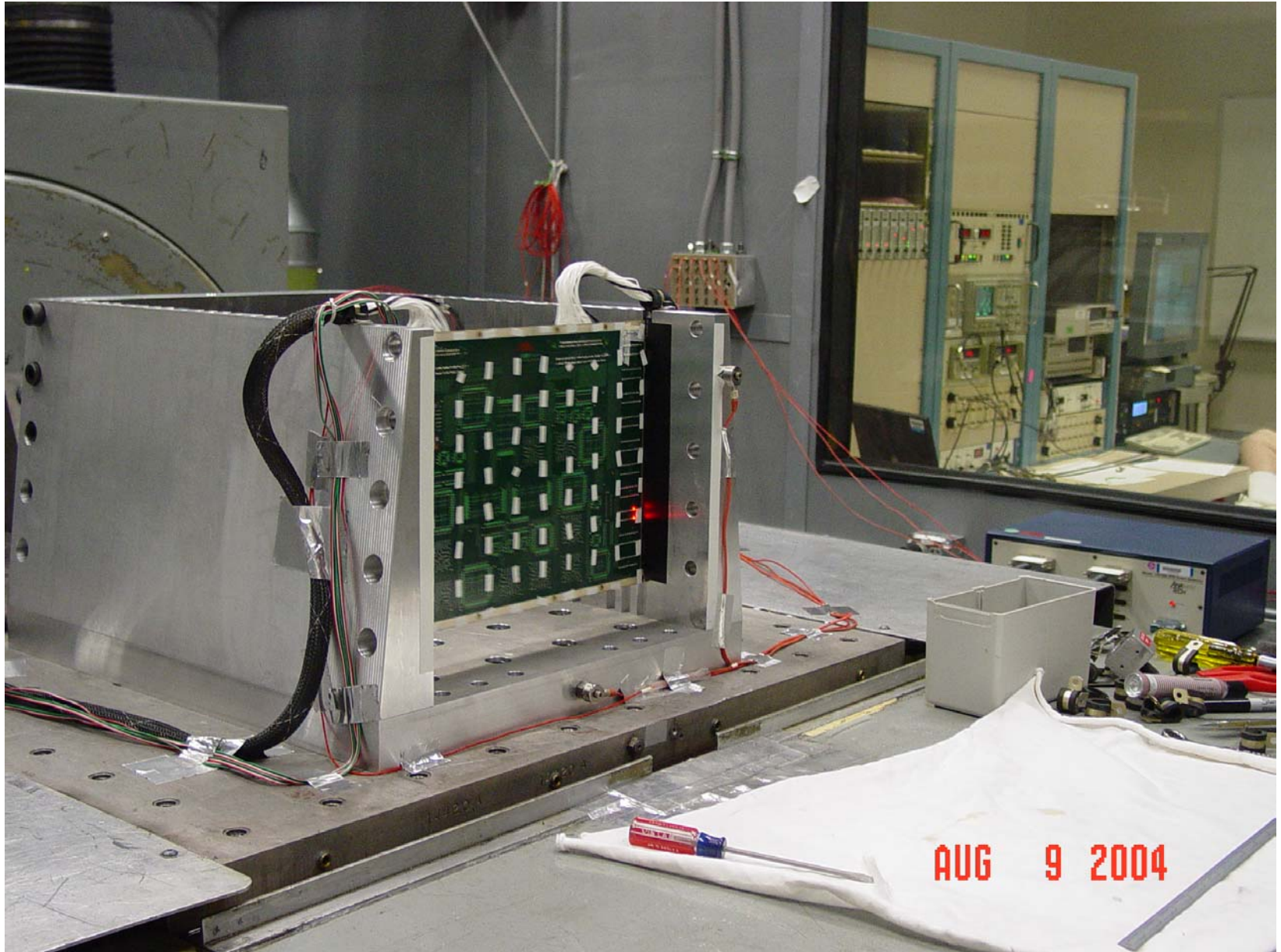
Strain Gage Placement on “Pathfinder” Test Vehicle



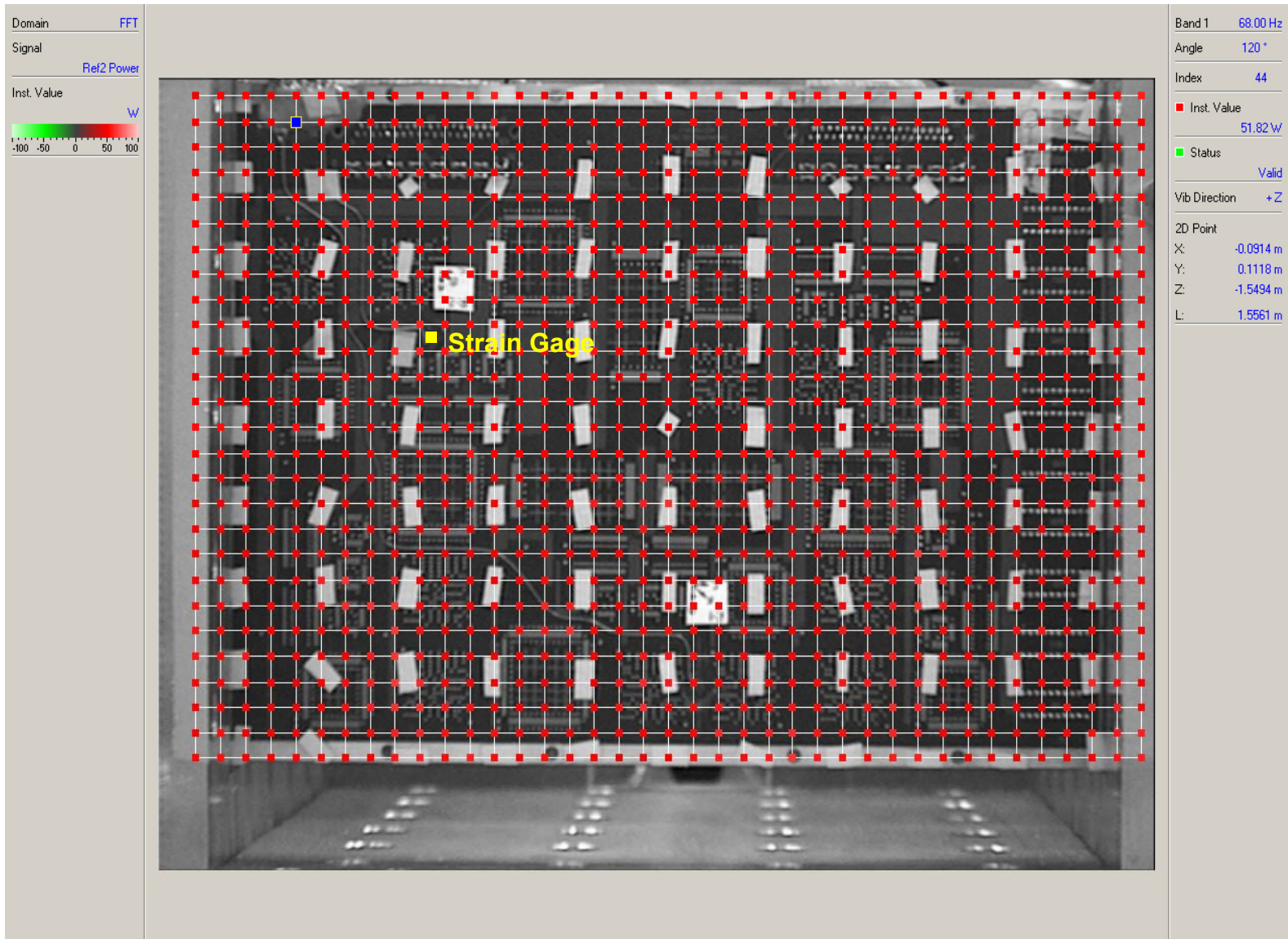
Laser Vibrometer System for Modal Analysis of “Pathfinder” Test Vehicle



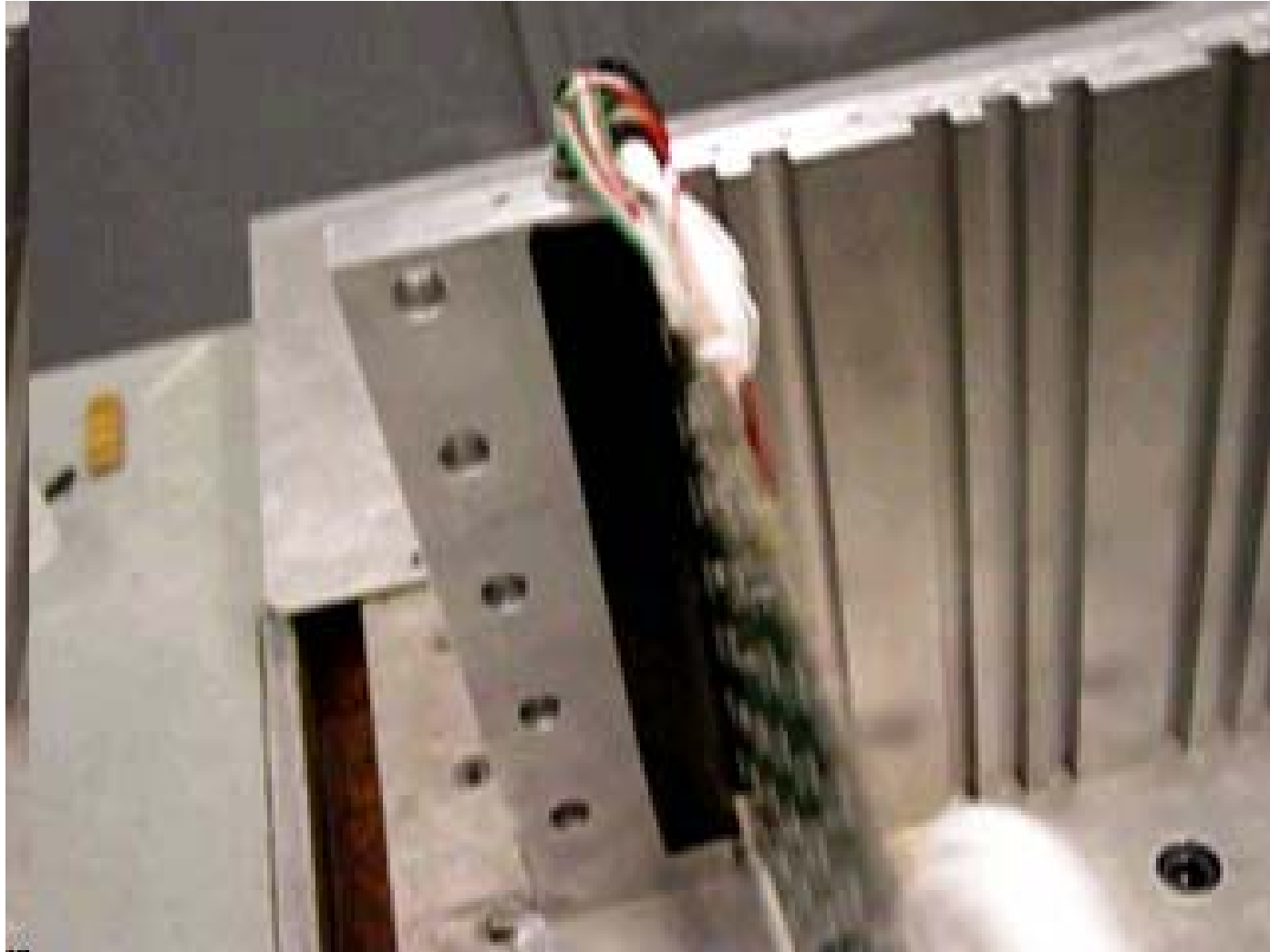
Laser Vibrometer Measures Velocities, Accelerations, Displacements



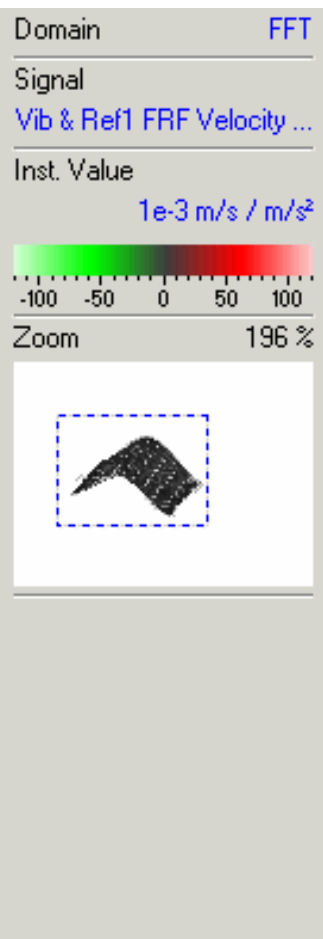
Laser Vibrometer's View of "Pathfinder" Test Vehicle (Showing Rows and Columns)



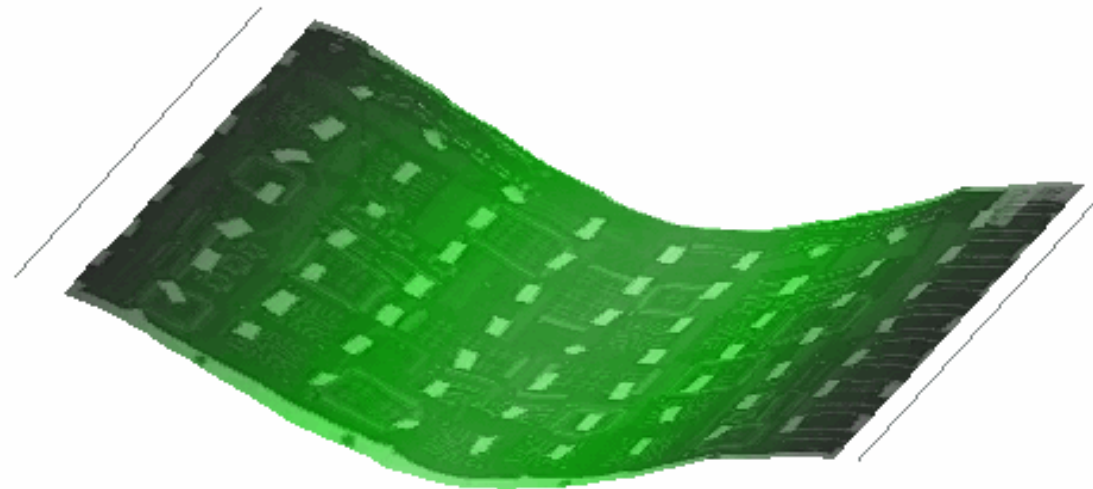
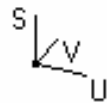
Pathfinder Test Vehicle in Z-Axis (16.0 Grms)



Operating Deflection Shape at 72 Hz



Lead Free Circuit Board Vibration Test - 72Hz Operating Deflection shape



Band 1 72.00 Hz

Angle 0°

Boeing's prediction of first resonance was 82 Hz


It is very important to understand that during vibration testing, the vibration environment at a given location on a test vehicle can be very different from the vibration environment at a different location on the same vehicle during the same test. This means that only identical components in identical locations on identical test vehicles can be directly compared. It also implies that the test solder must be used on one set of test vehicles and the control solder on a second set of test vehicles.

Operating Deflection Shape at 101.5 Hz


Domain [FFT](#)

Signal
[Vib & Ref1 FRF Velocity ...](#)

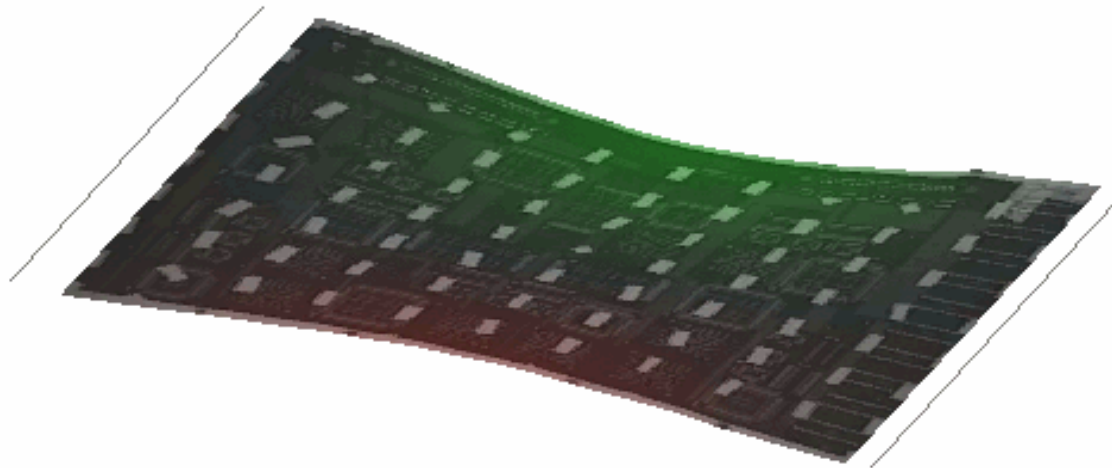
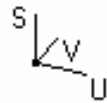
Inst. Value
 $1e-3 \text{ m/s} / \text{m/s}^2$



Zoom 200 %



Lead Free Circuit Board Vibration Test - 101.5Hz Operating Deflection shape



Band 1 [101.5 Hz](#)

Angle [0 °](#)


Operating Deflection Shape at 411.5 Hz

Domain **FFT**

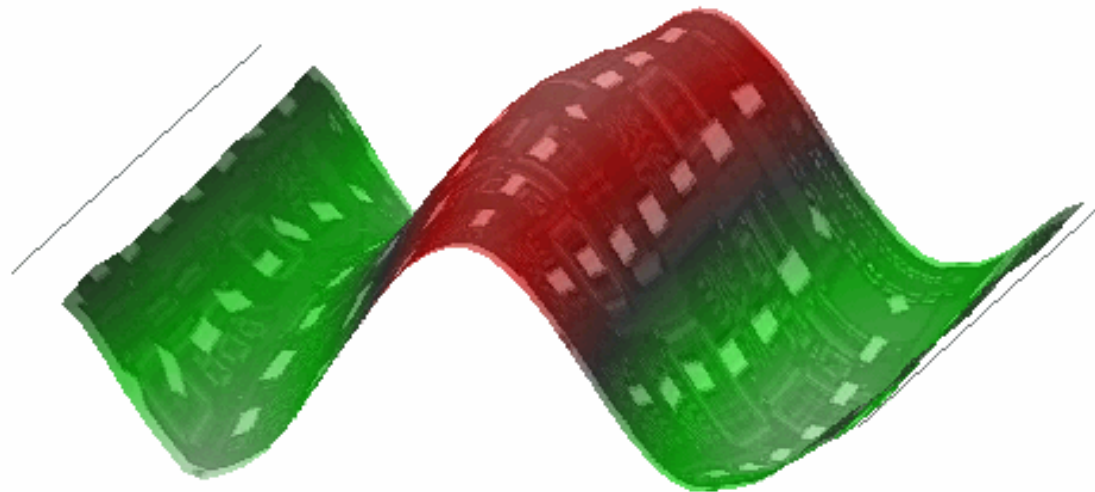
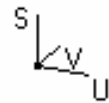
Signal
Vib & Ref1 FRF Velocity ...

Inst. Value
 $1e-3 \text{ m/s} / \text{m/s}^2$

Zoom 197 %



Lead Free Circuit Board Vibration Test - 411.5Hz Operating Deflection shape



Band 1 **411.5 Hz**

Angle **0°**

Displacement vs. Frequency

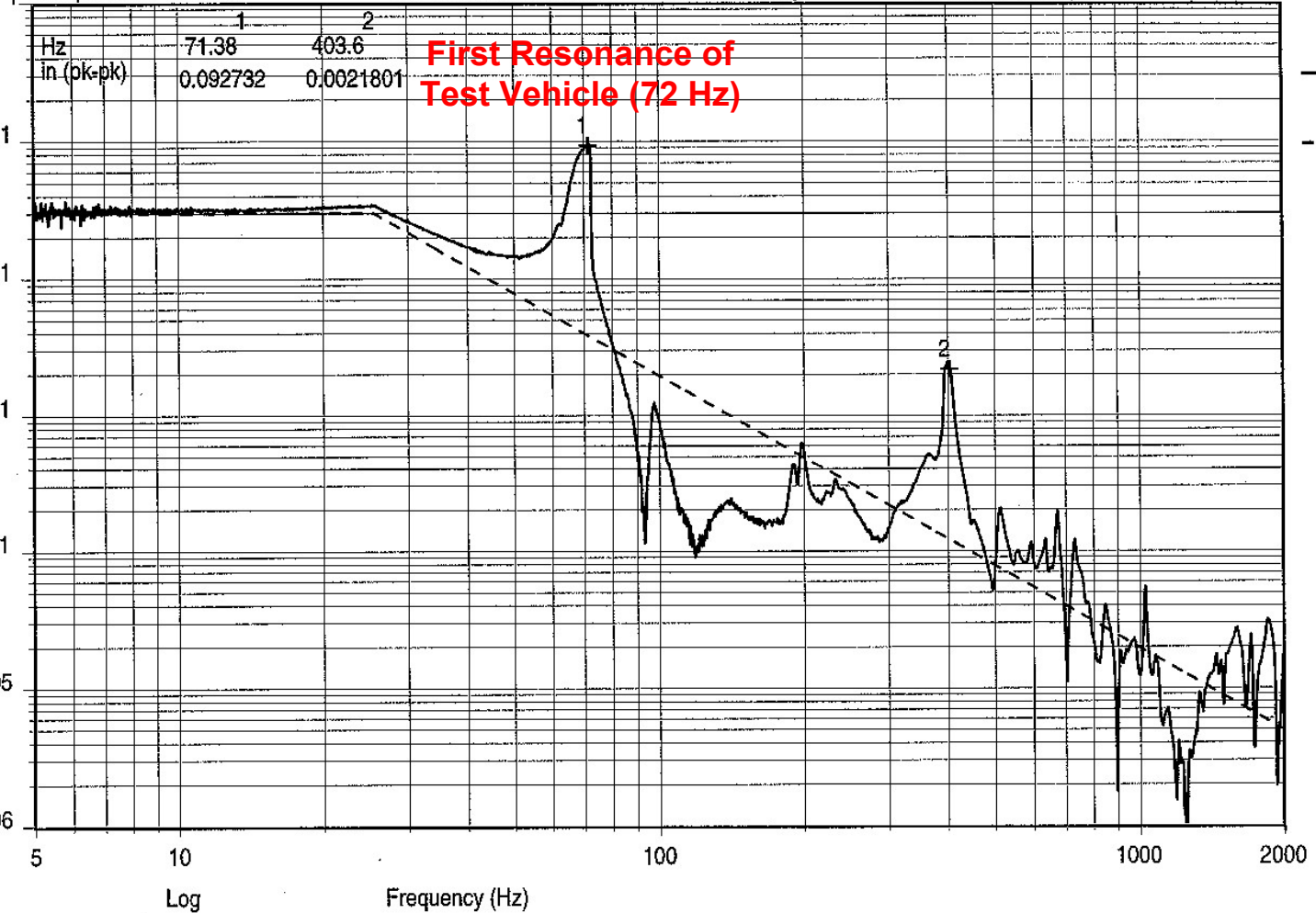
(the most displacement is at 72 Hz)

Sweep Number: 1.00
Sweep Rate 1: 1.000 oct/min
Compression: Variable

Elapsed Time: 000:08:39
Filter Type: Proportional
Fundamental: 80.000 %, BB RMS: 509. mcyc

Remaining Time: 000:00:00
Test Range: 5.000, 2000.000 Hz
Points Per Sweep: 2000

*Auxiliary Ch 8
Fundamental
Reference



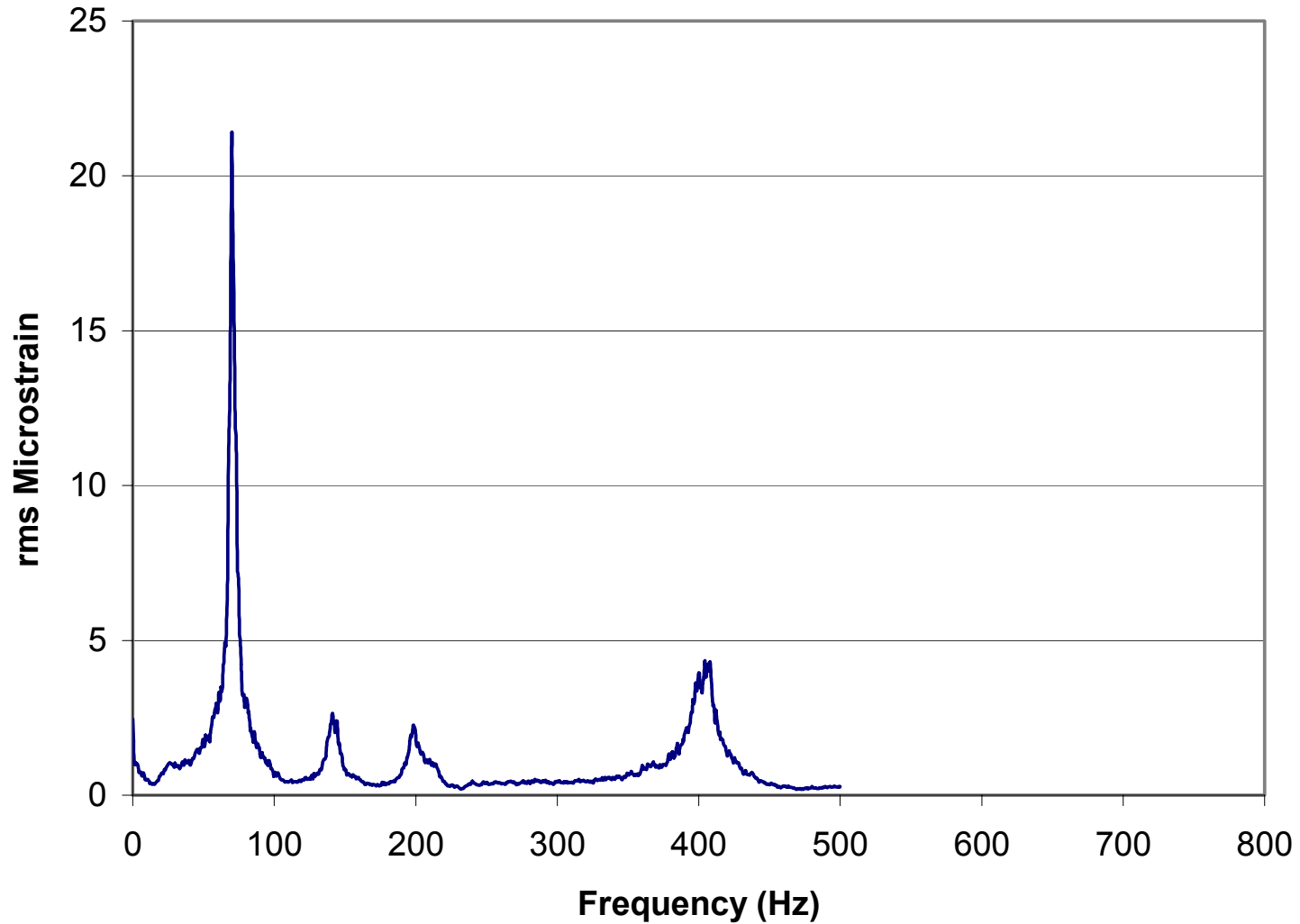
08:45:52
02-Sep-2004

TN: 2052 No lead Circuit Board, 1st Set of 15 Boards
RUN#6 Z-Axis, SINE SWEEP 1.0 Gpk Operator:TDK
Sine Test Name: tn2052_NoLead_Circuit_bd.002

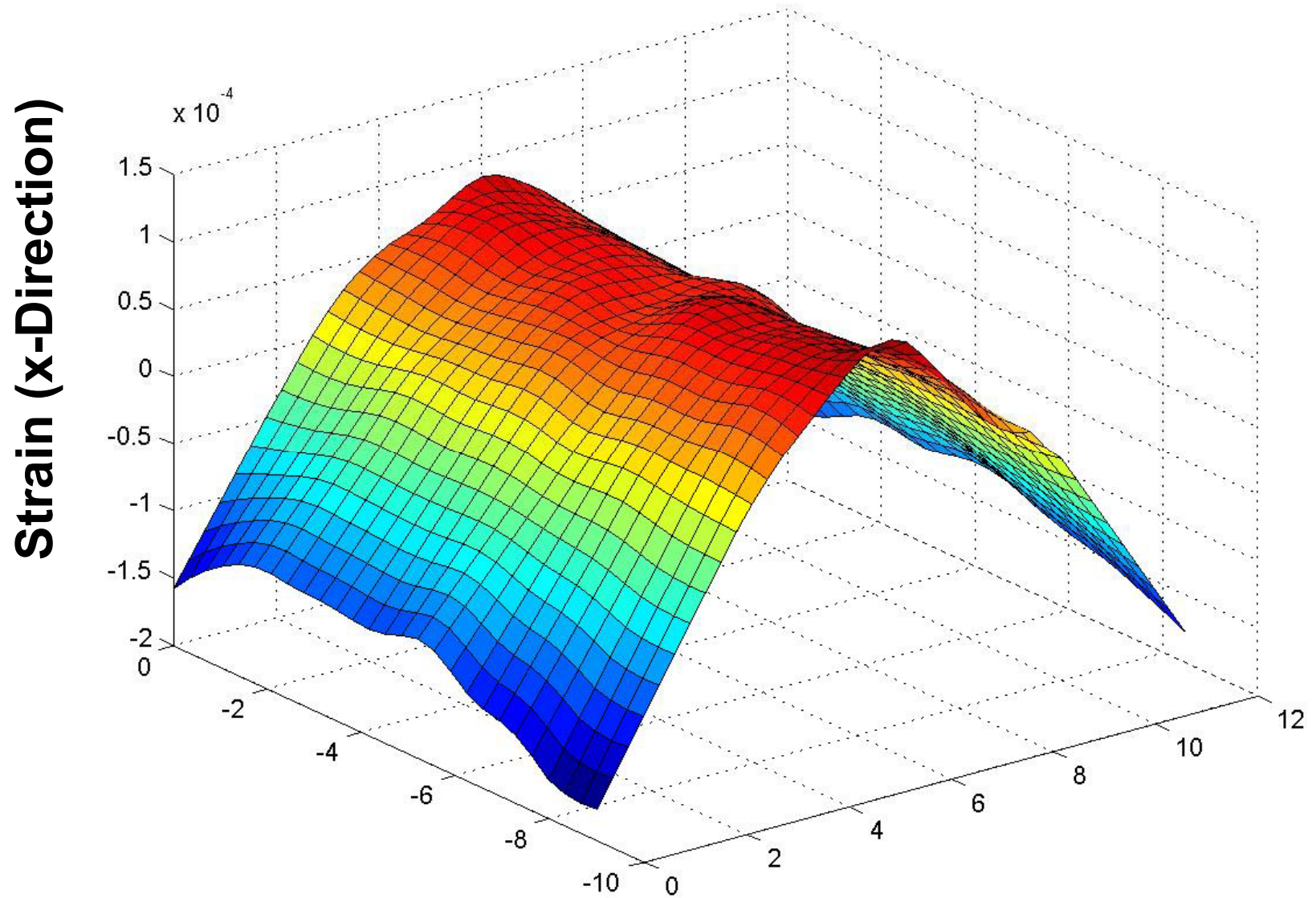
Z RESPONSE, Board # 008

Strain vs. Frequency, 9.9 Grms

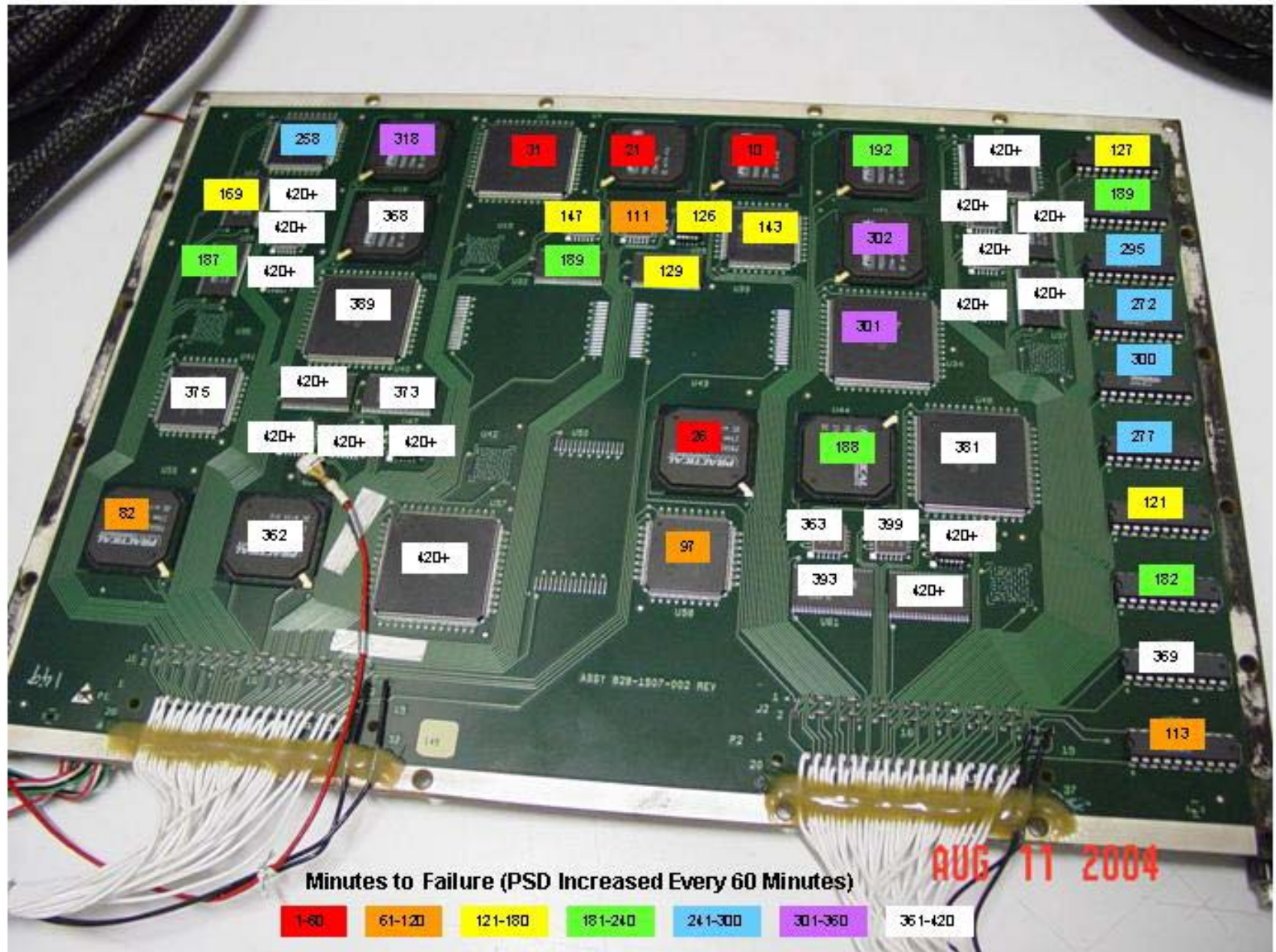
(the most strain is at 72 Hz)



Strain Field at 72 Hz (from Laser Vibrometer Measurements)



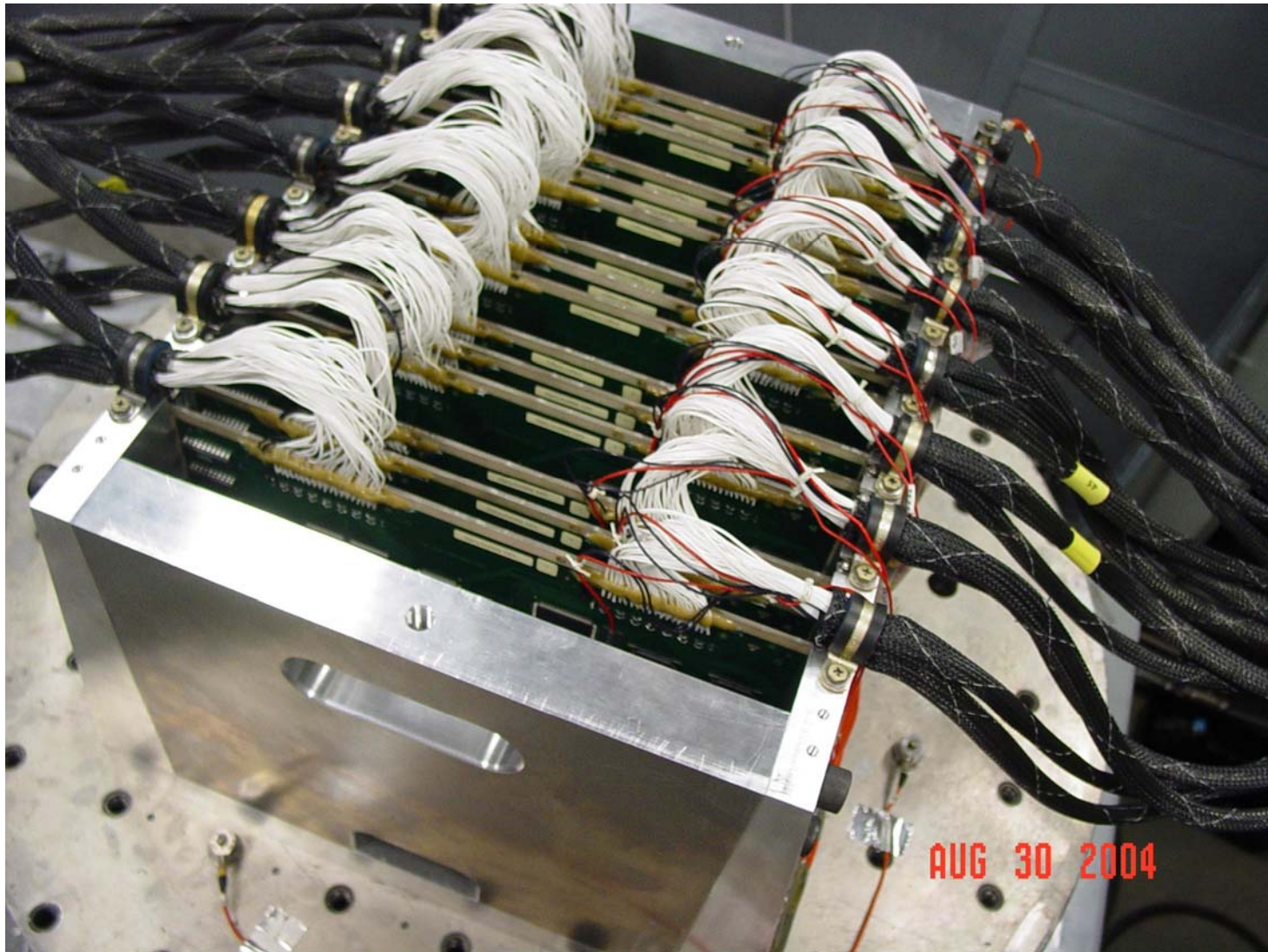
Times to Failure for "Pathfinder" Components (Minutes)



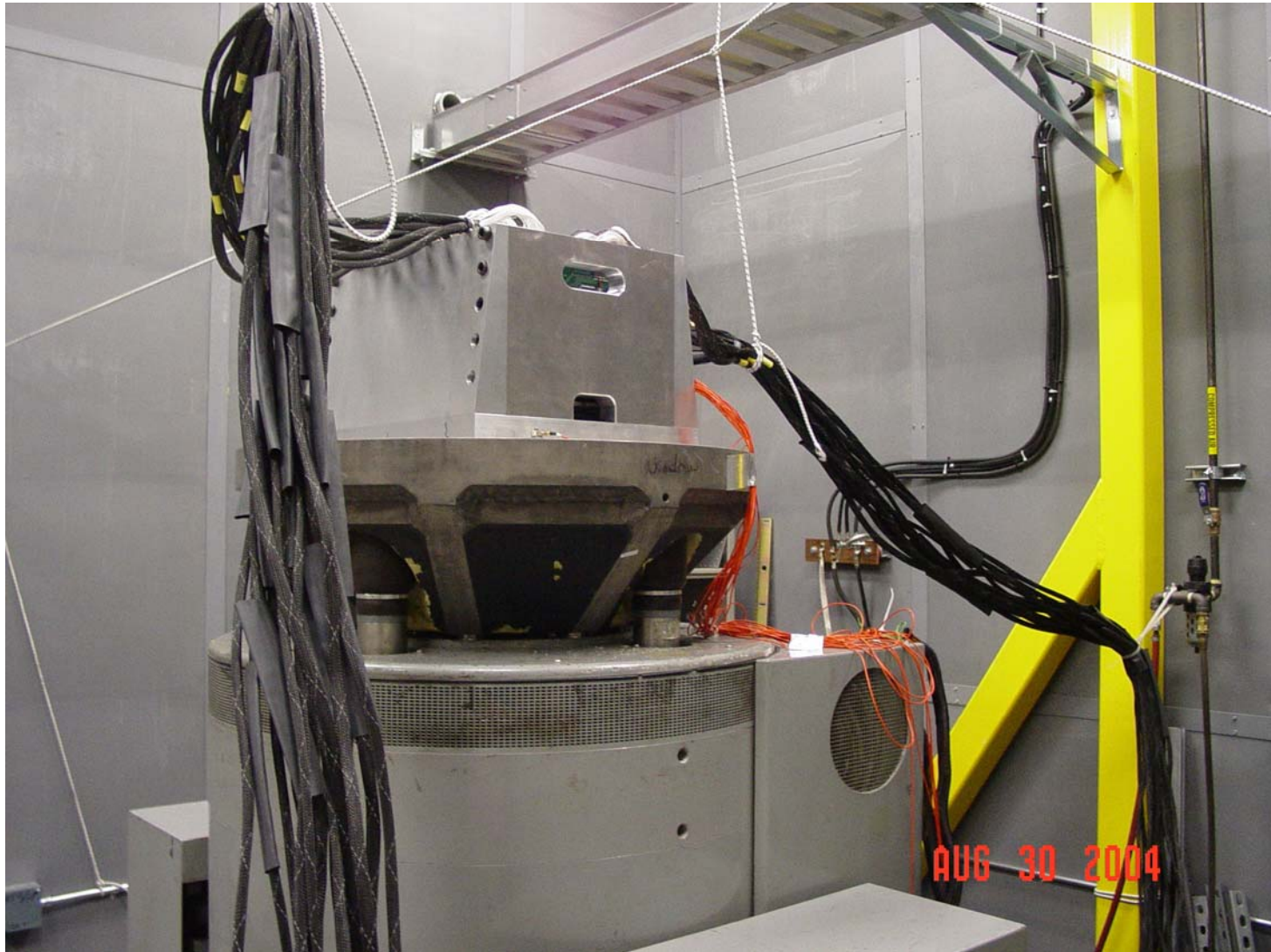
Vibration Test

- All “manufactured” and “reworked” test vehicles were then tested (2 batches of 15 vehicles).
- Test vehicles were visually inspected after test.
- Final report was written.

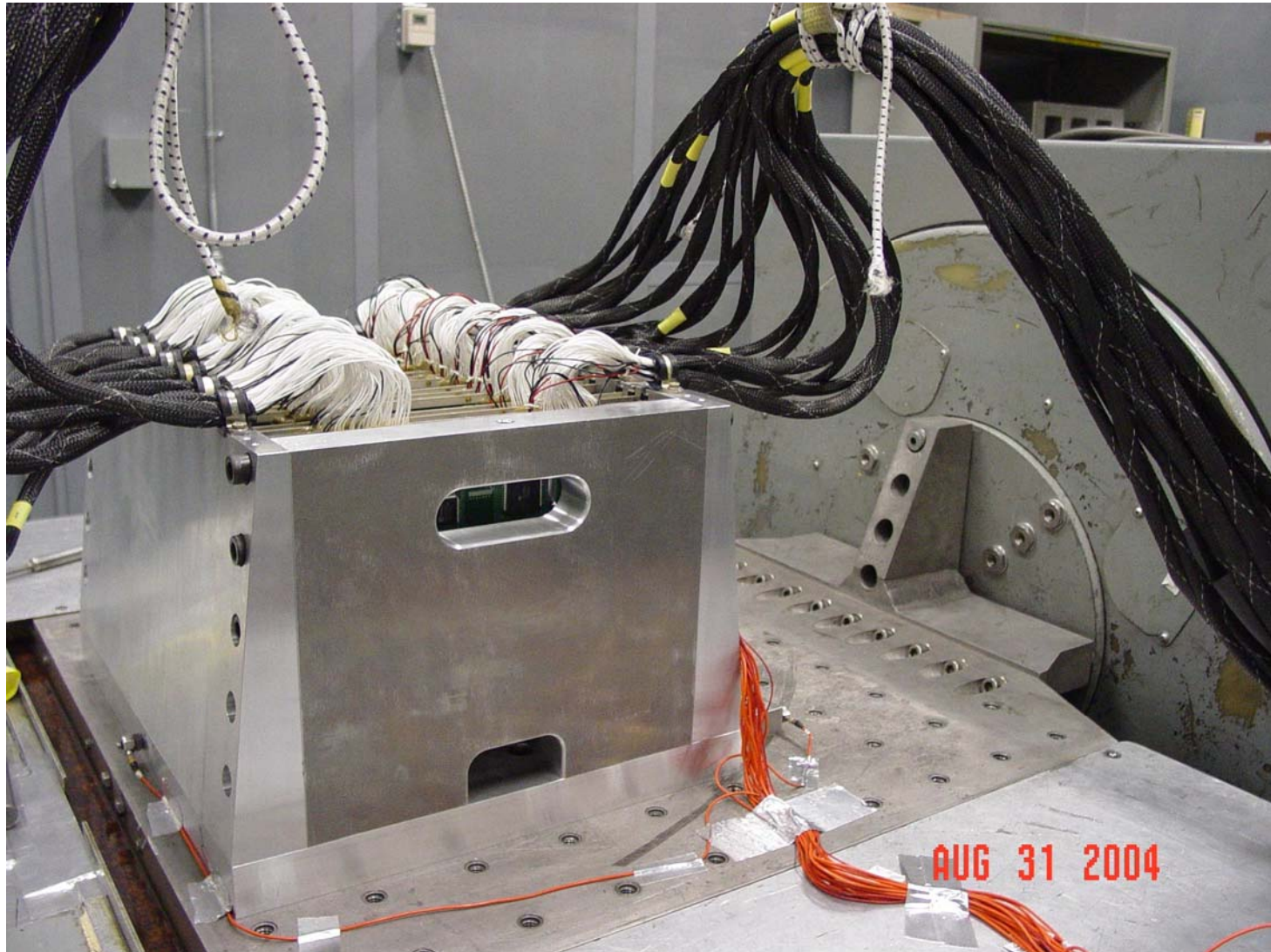
Test Vehicles in Fixture



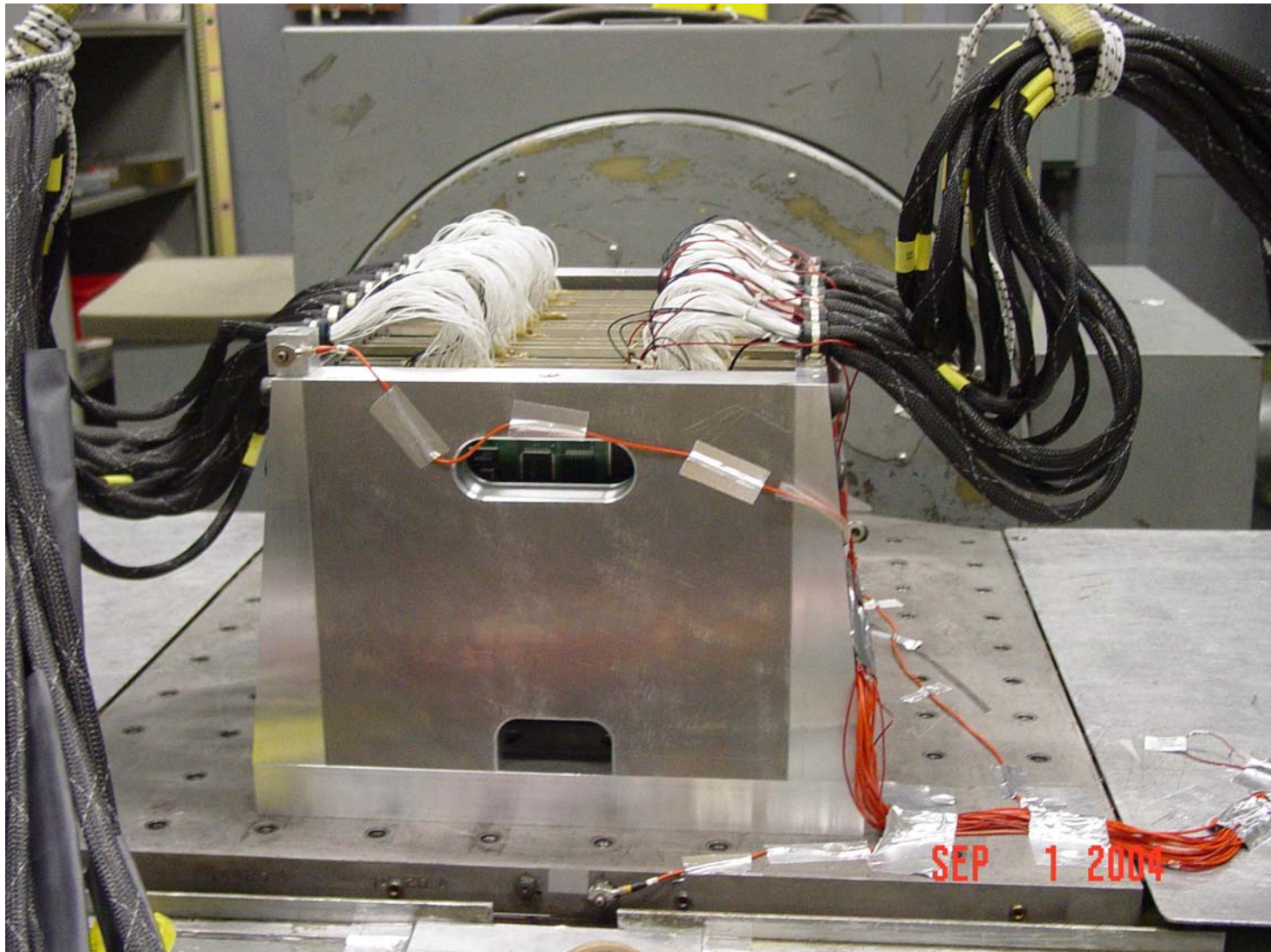
Vibration Table (Y-axis)



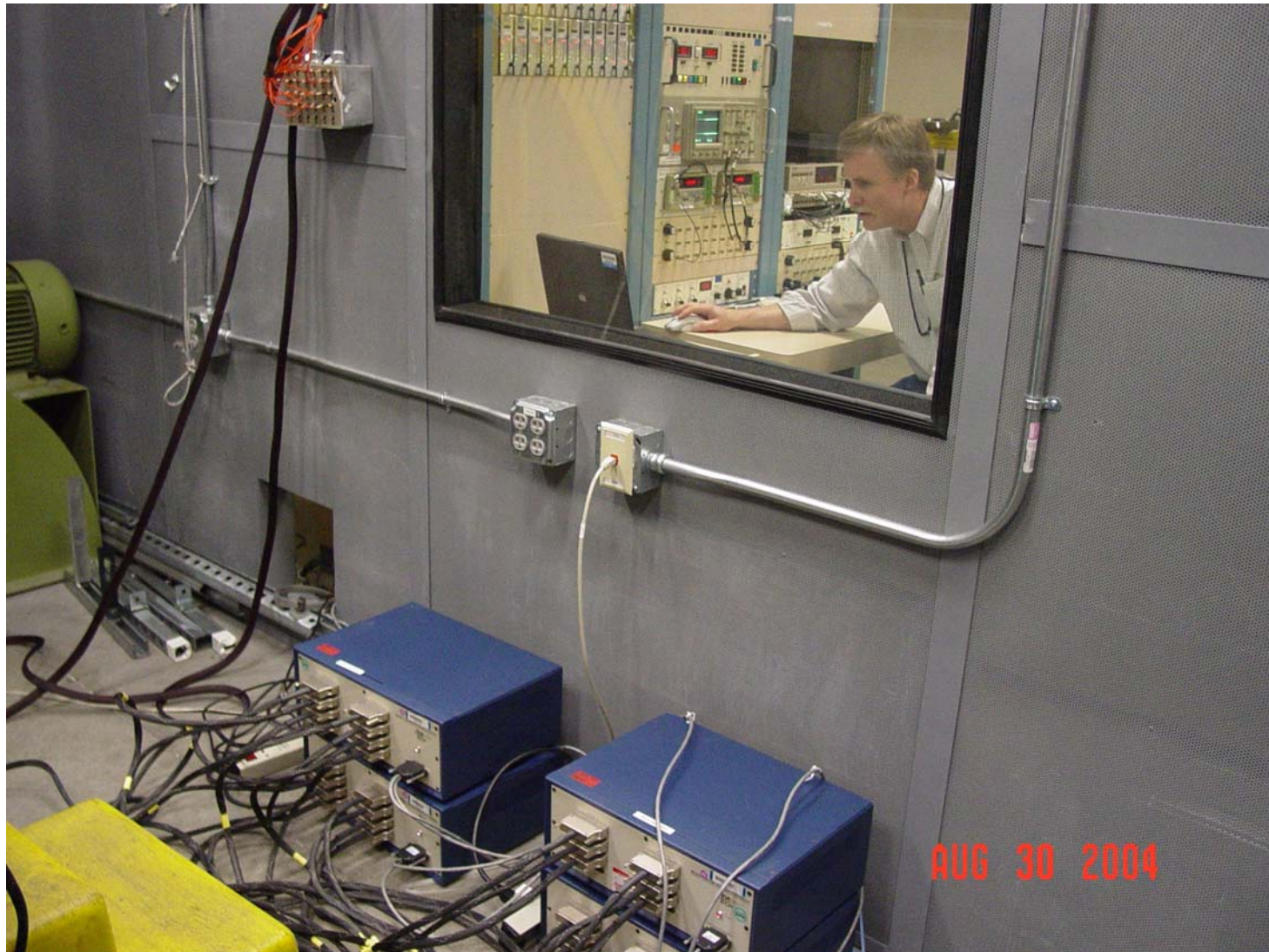
Vibration Table (X-axis)



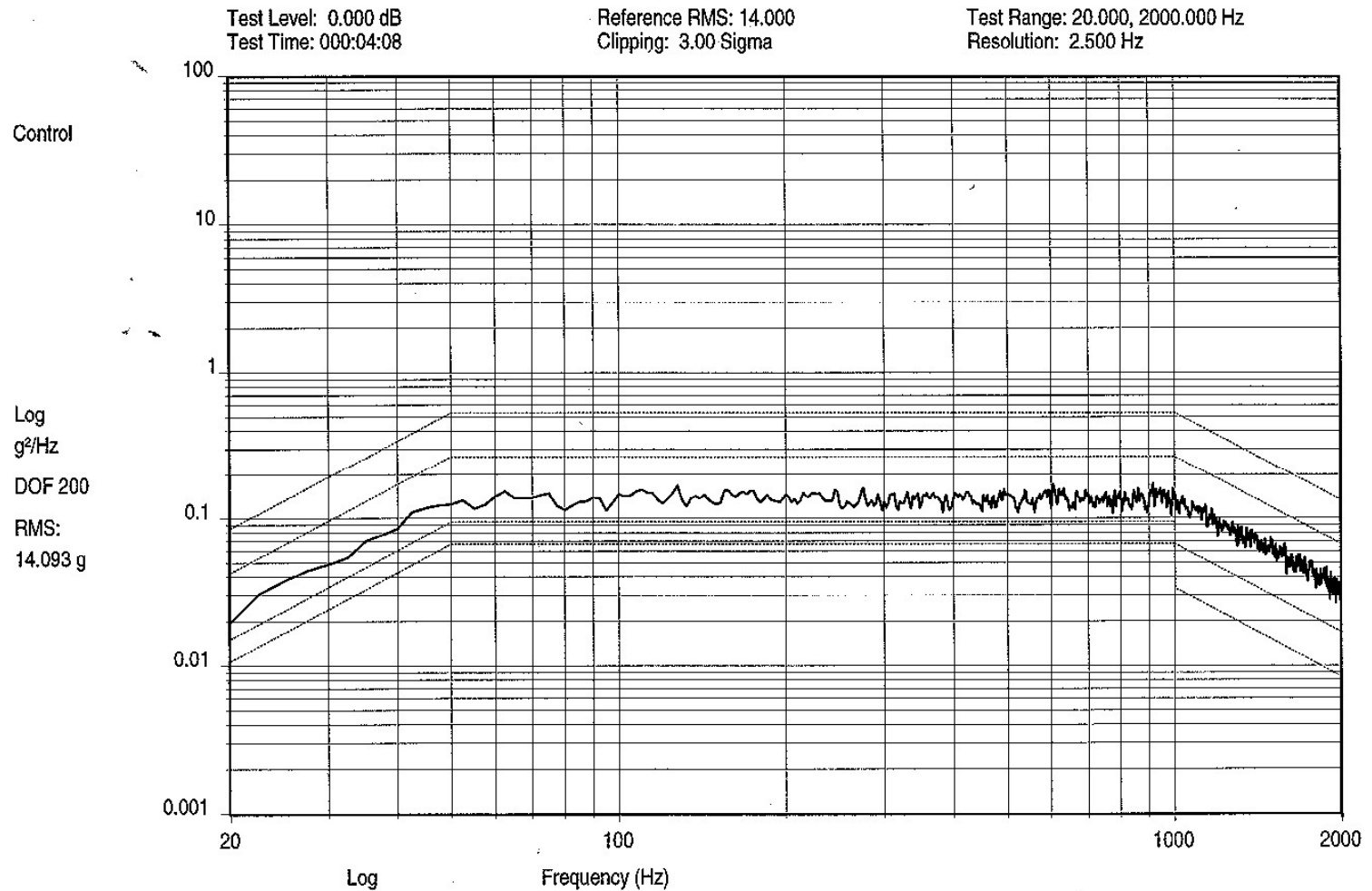
Vibration Table (Z-axis)



Anatech Event Detectors



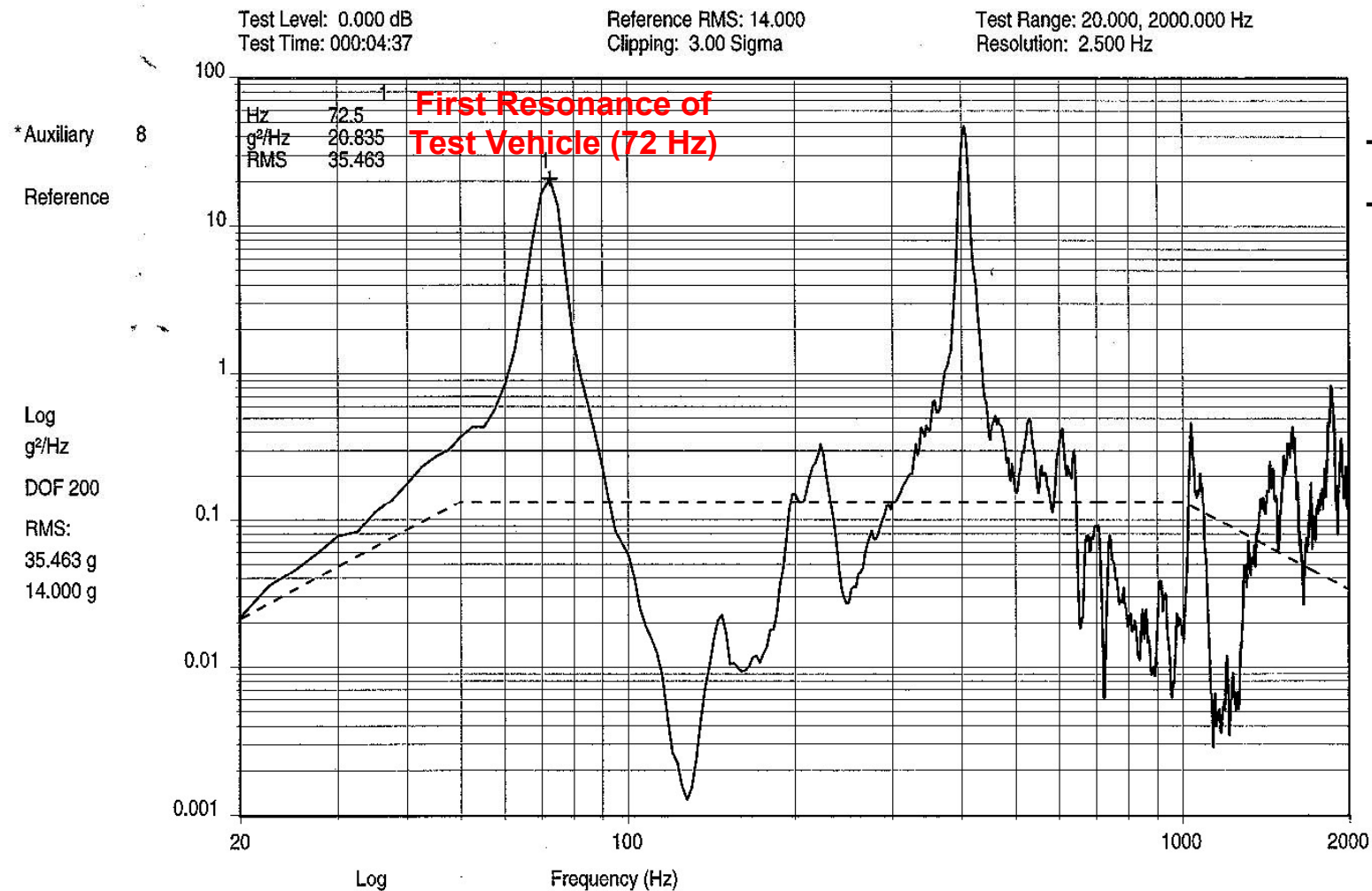
Accelerometer Measurement of Input into Test Vehicle



14:52:47
01-Sep-2004

TN#2052 1st set of 15 Circuit Boards
Run#5 Level # 3 14.0 Grms, Z-axis, Operator: TDK
Test Name: tn2052_NoLead_PWA.019

Accelerometer Measurement of Test Vehicle Response

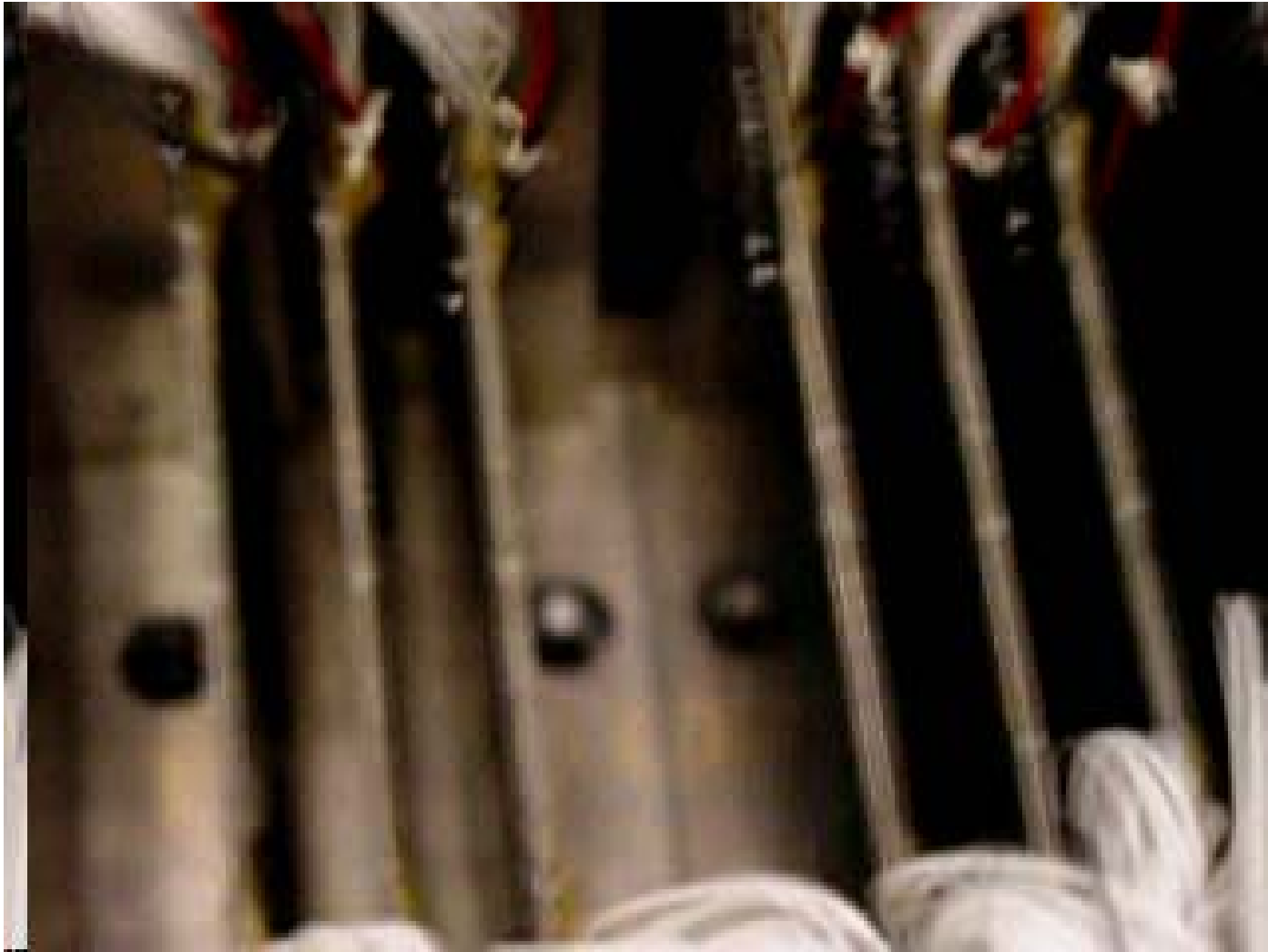


14:53:15
01-Sep-2004

TN#2052 1st set of 15 Circuit Boards
Run#5 Level # 3 14.0 Grms, Z-axis, Operator: TDK
Test Name: tn2052_NoLead_PWA.019

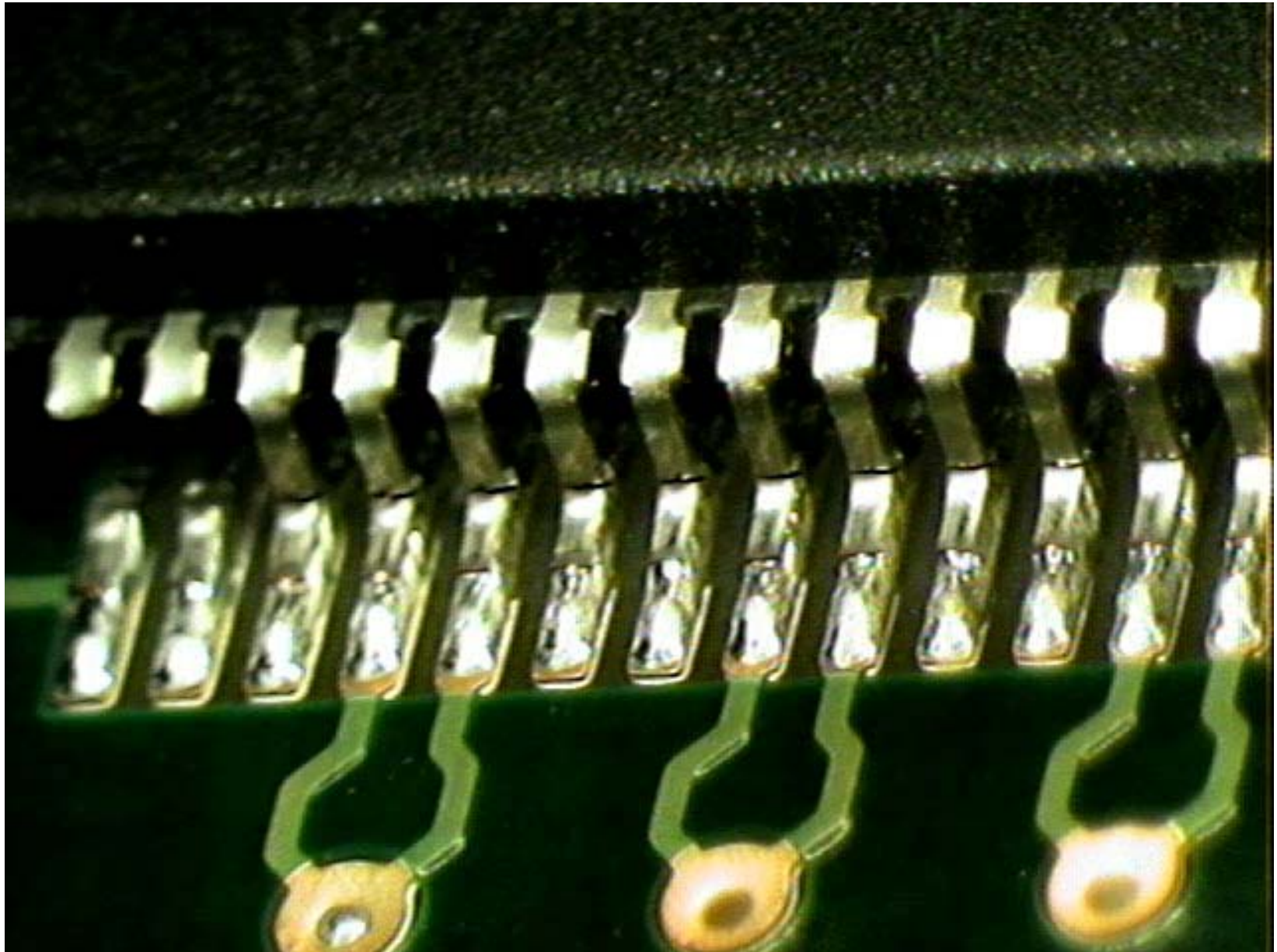
Z RESPONSE, Board # 008

Test Vehicles in Z-Axis (20.0 Grms)



	Test Level	% of Components Failed (Manufactured Boards)
Y-axis	9.9 Grms	0
X-axis	9.9 Grms	0
Z-axis	9.9 Grms	7.6
Z-axis	12.0 Grms	18.0
Z-axis	14.0 Grms	29.3
Z-axis	16.0 Grms	39.3
Z-axis	18.0 Grms	47.0
Z-axis	20.0 Grms	55.6
Z-axis	28.0 Grms	68.8

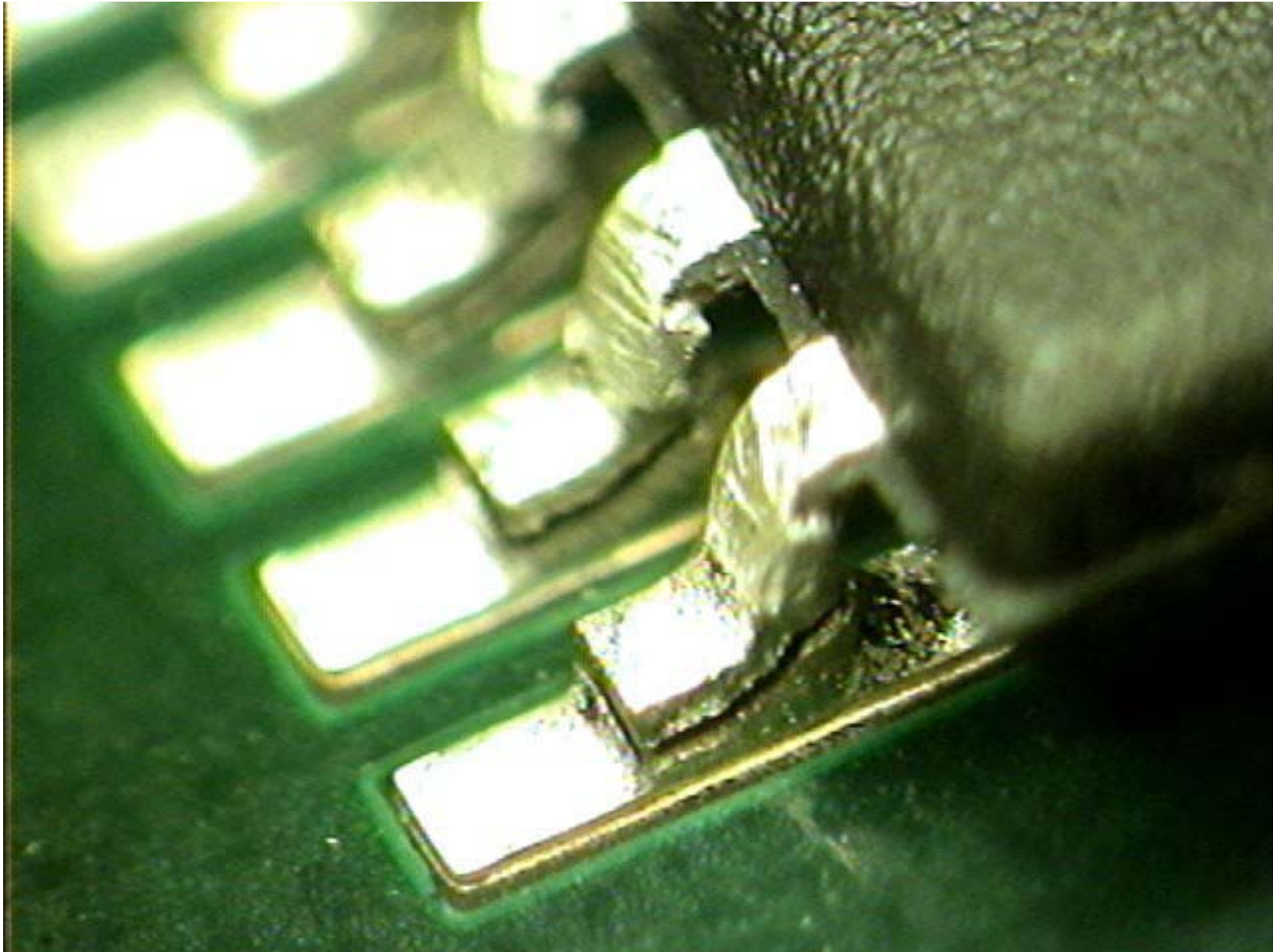
QFP's Had Missing and Broken Leads



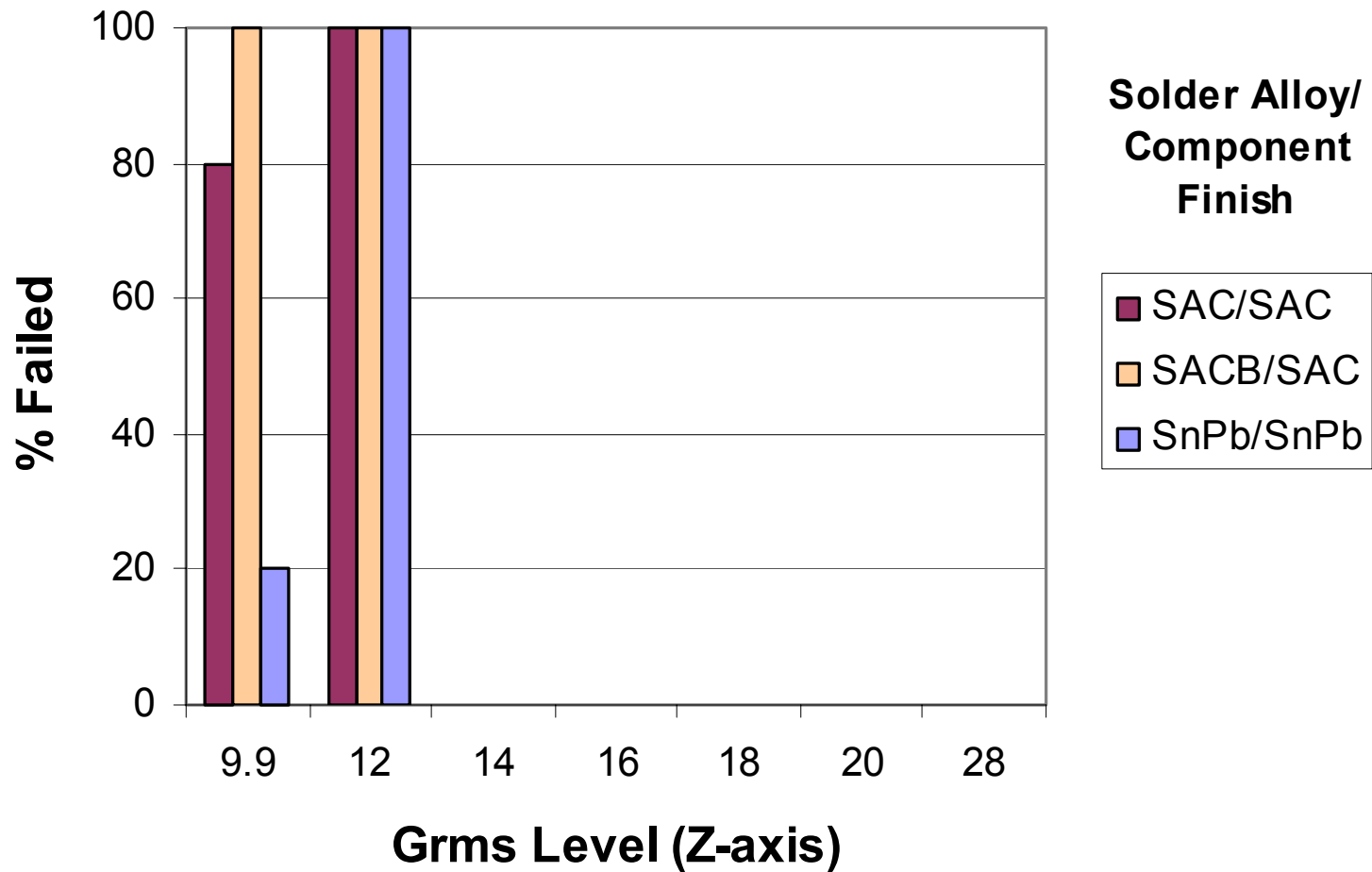
Typical DIP Failure



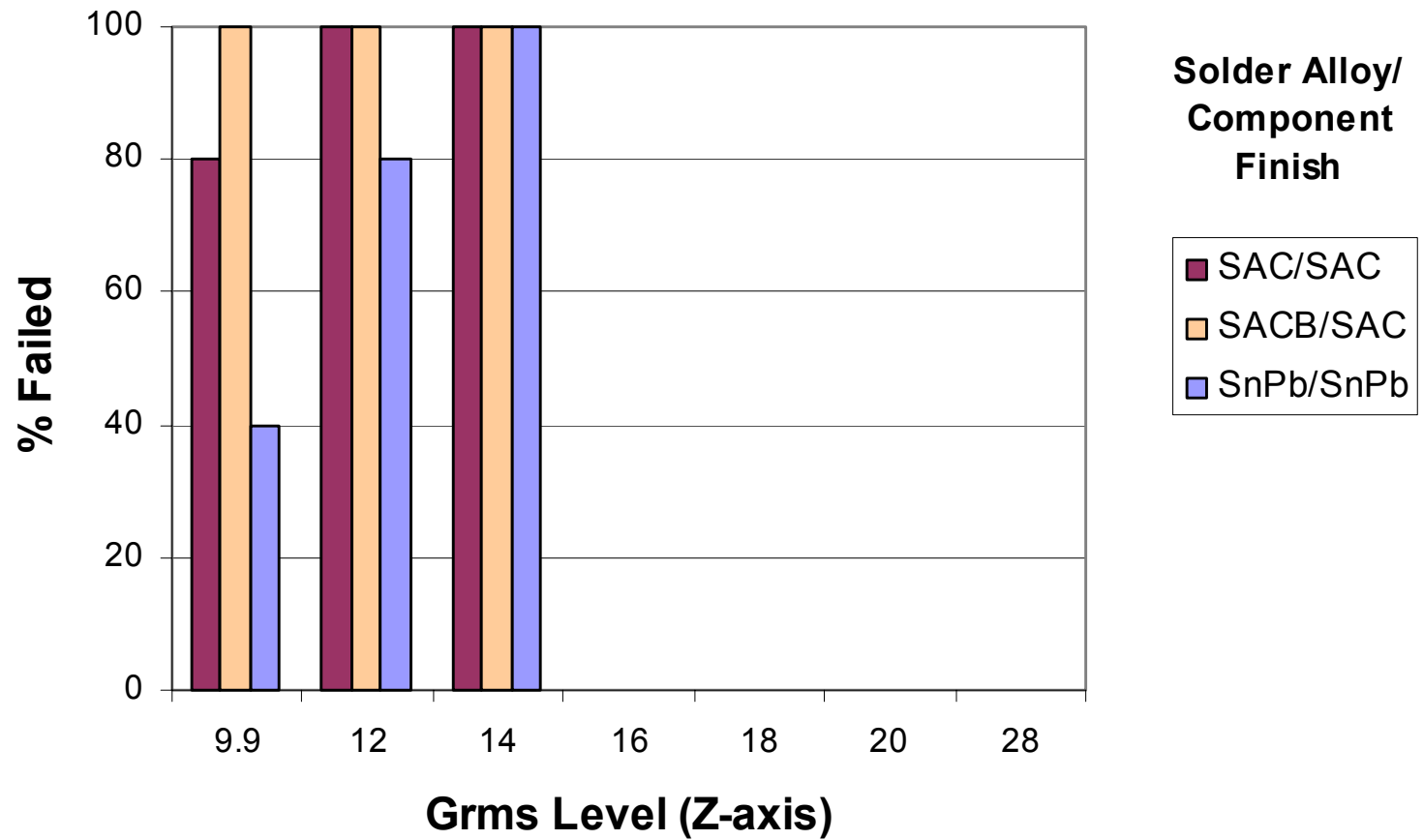
Typical TSOP Failure



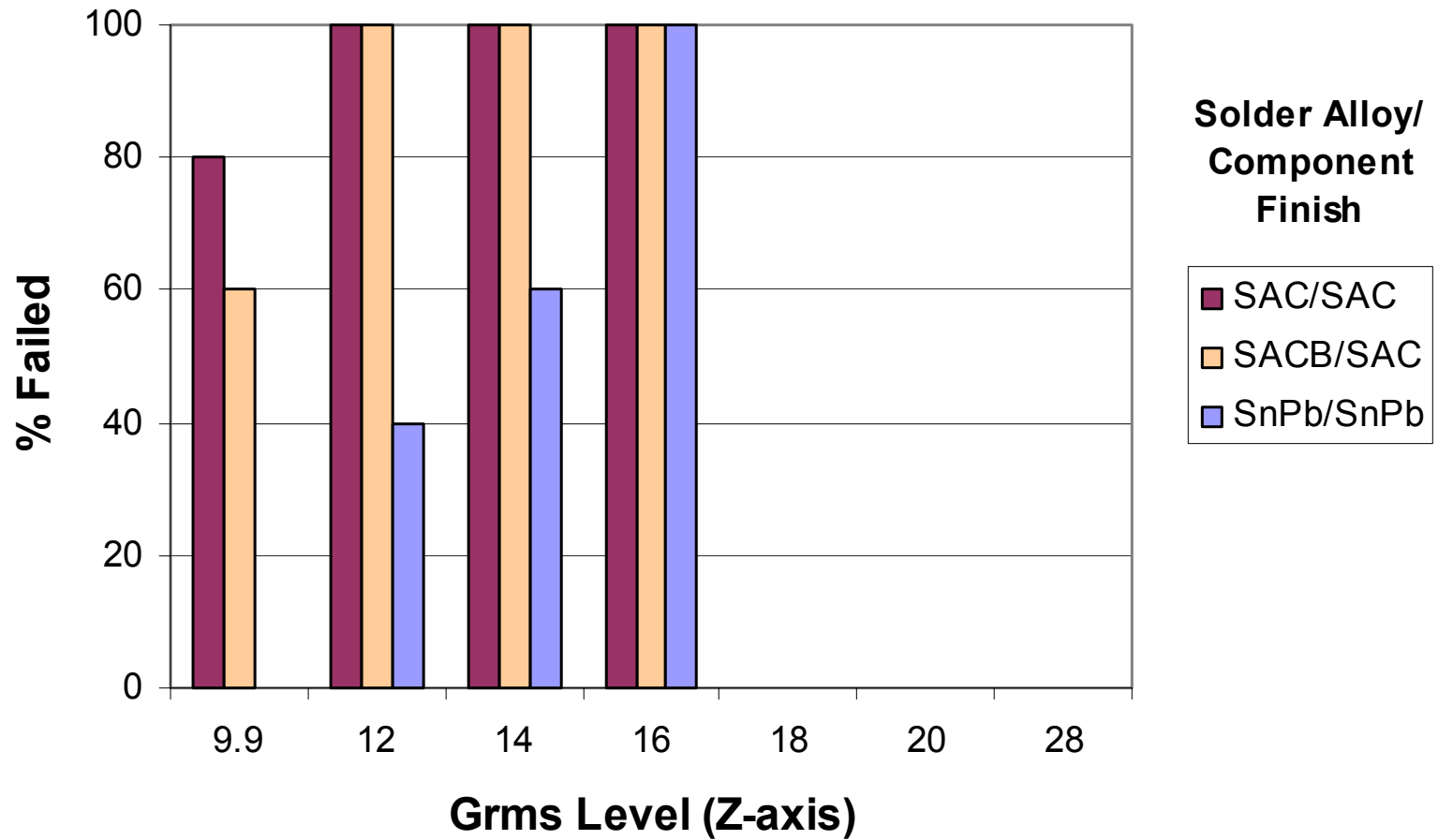
**"Manufactured" Test Vehicles
BGA-225
Component Location U43**



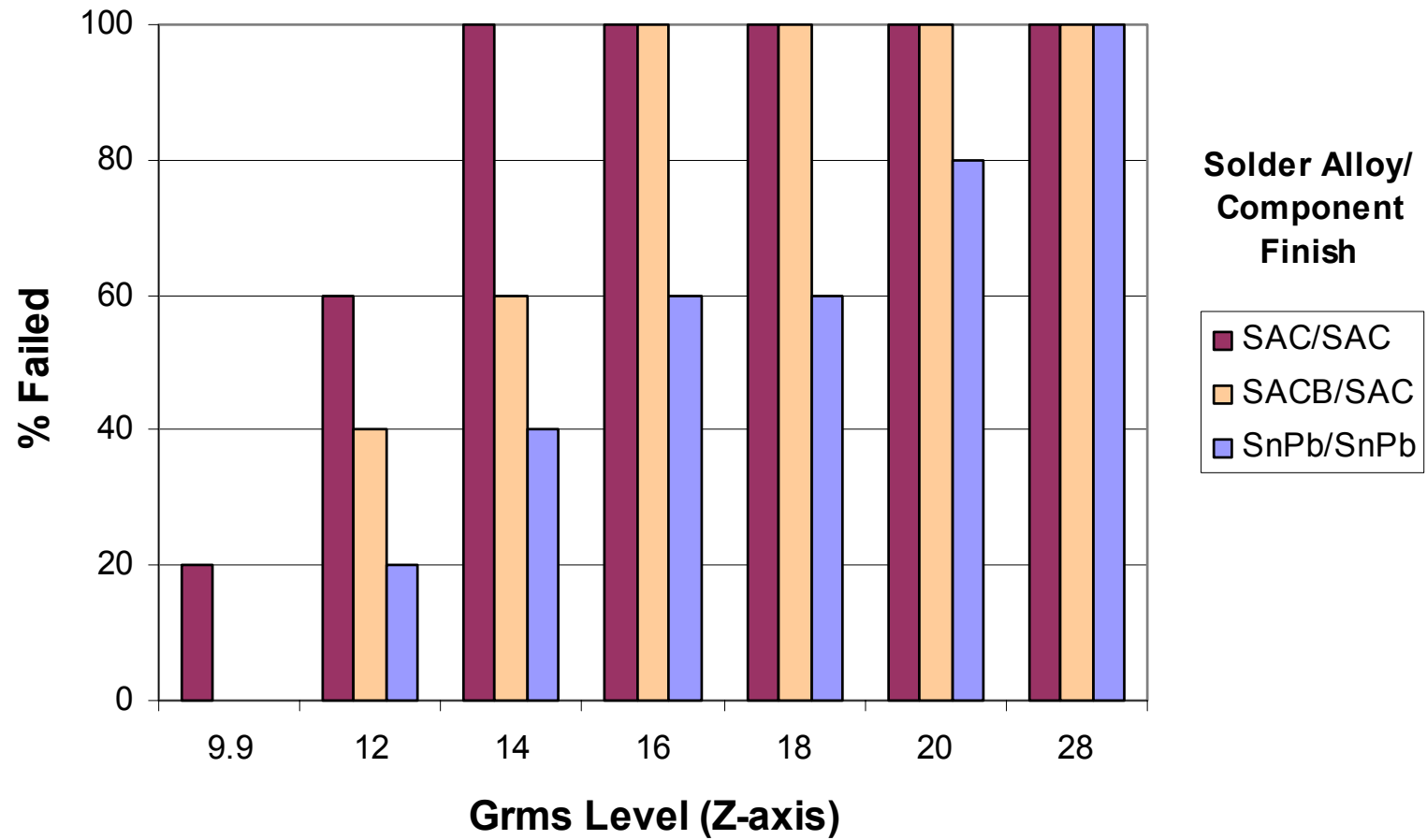
**"Manufactured" Test Vehicles
BGA-225
Component Location U4**



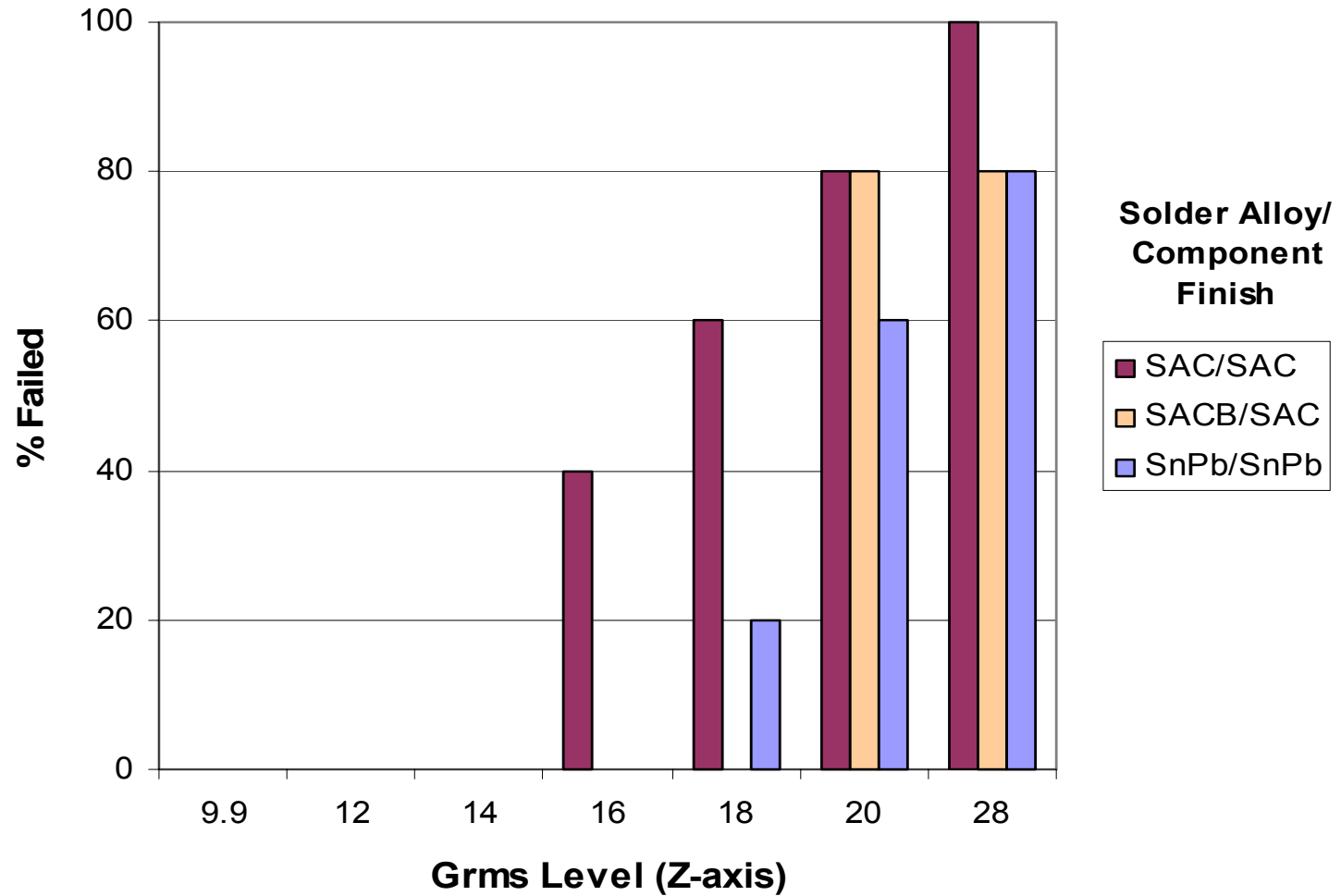
**"Manufactured" Test Vehicles
BGA-225
Component Location U55**



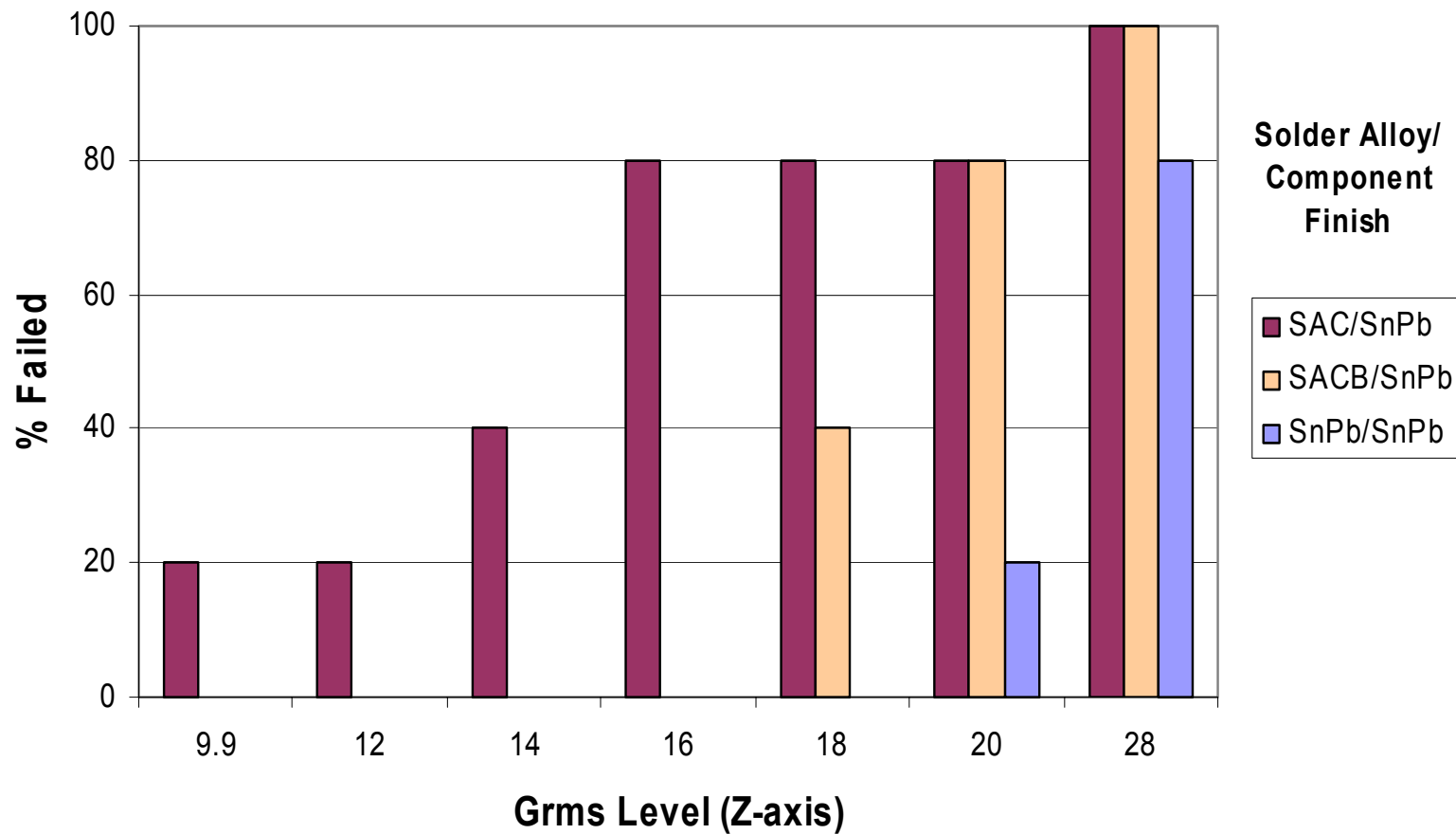
**"Manufactured" Test Vehicles
BGA-225
Component Location U6**



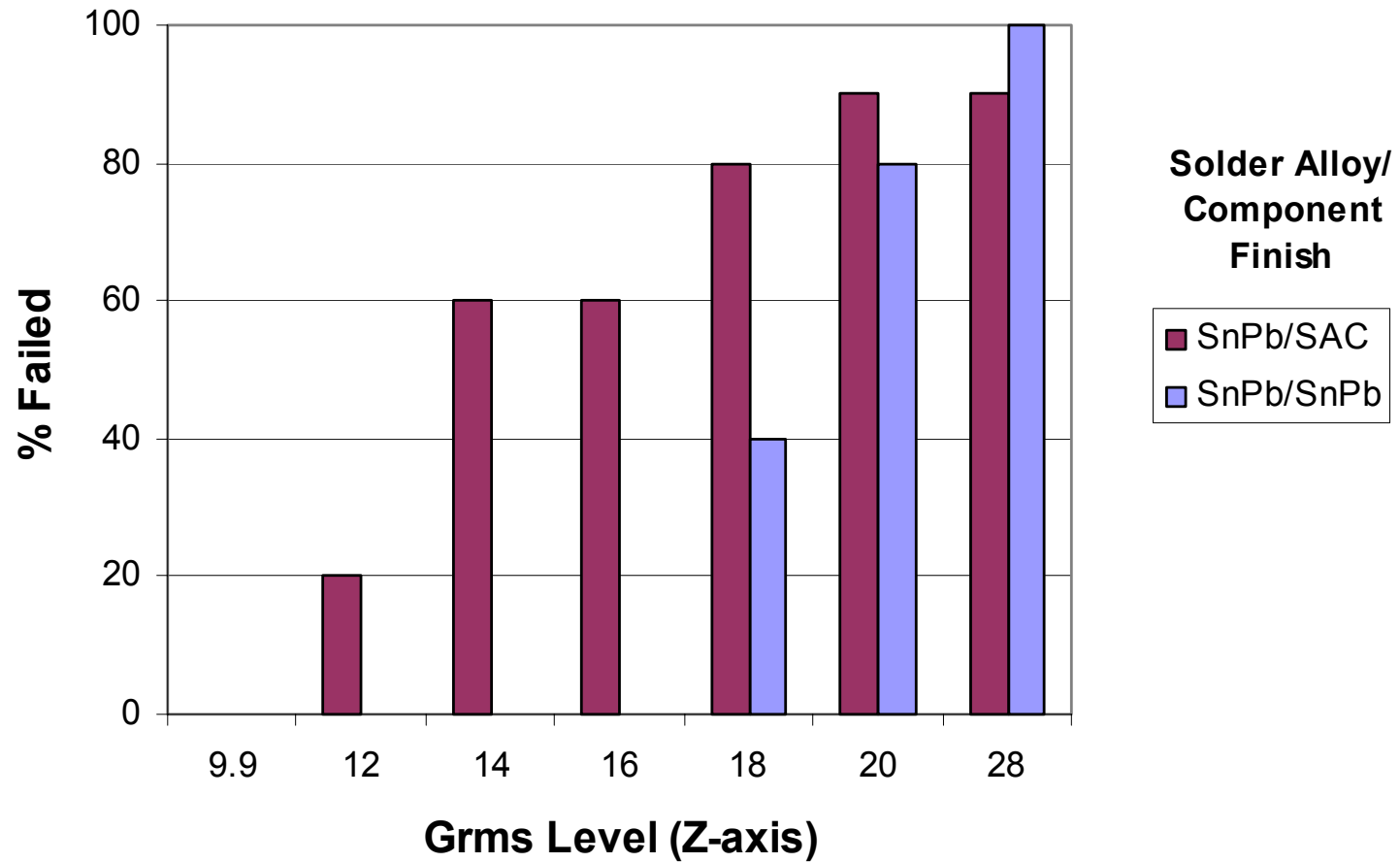
**"Manufactured" Test Vehicles
BGA-225
Component Location U18**



"Manufactured" Test Vehicles
BGA-225
Component Location U56



**"Reworked" Test Vehicles
BGA-225
Component Location U6**

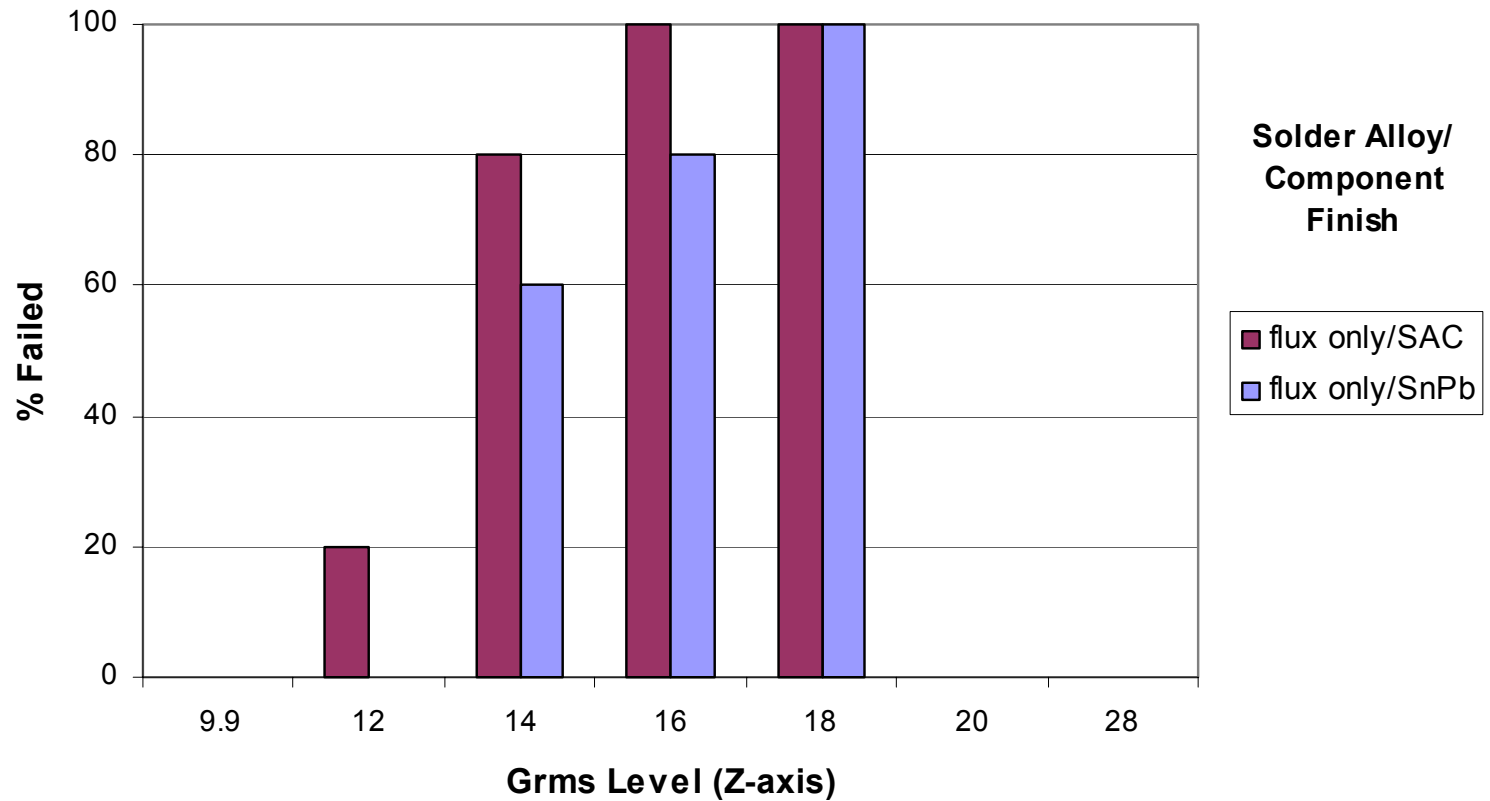


"Reworked" Test Vehicles

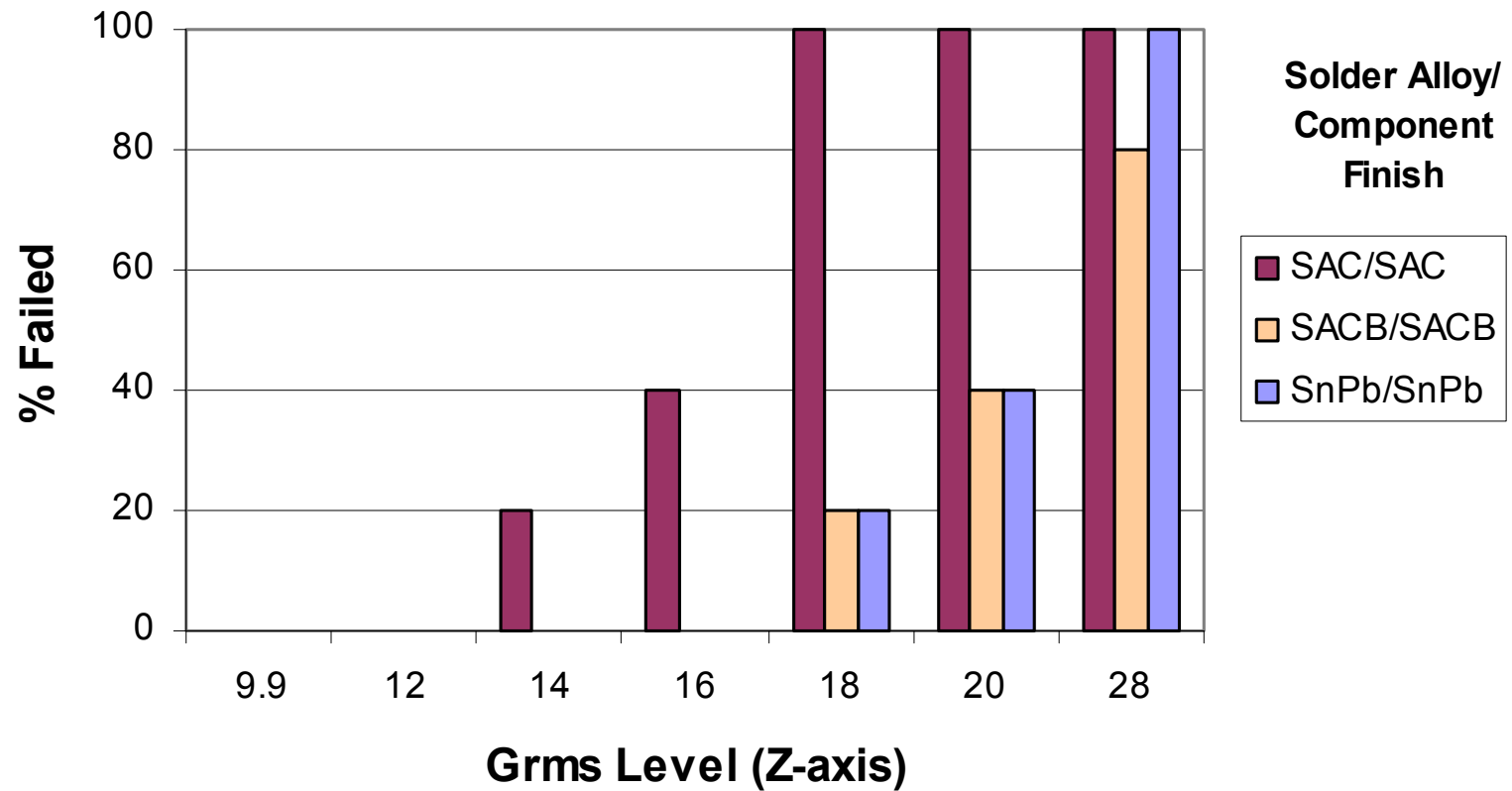
BGA-225

Component Location U18

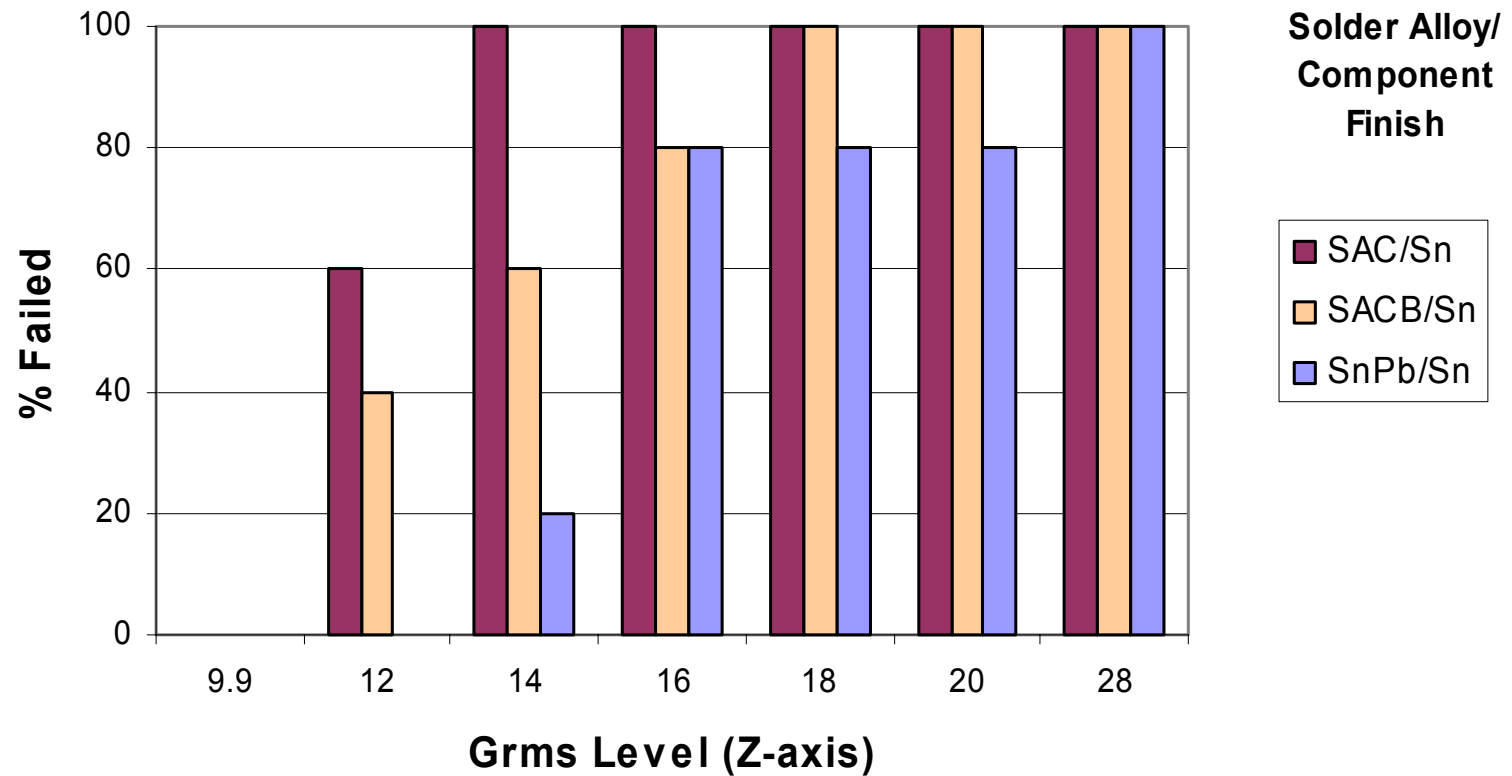
Component was Reworked



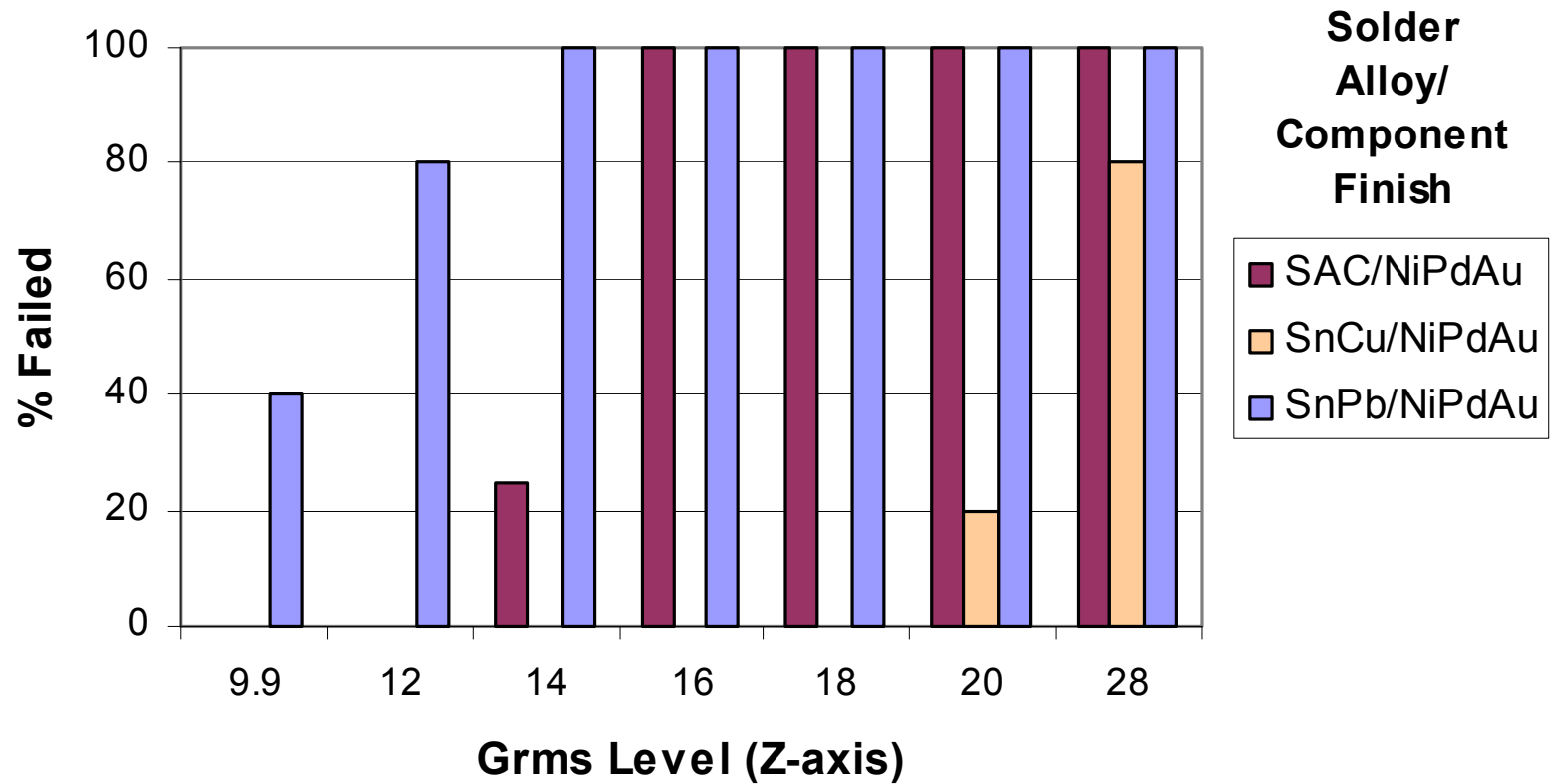
**"Manufactured" Test Vehicles
CLCC-20
Component Location U52**



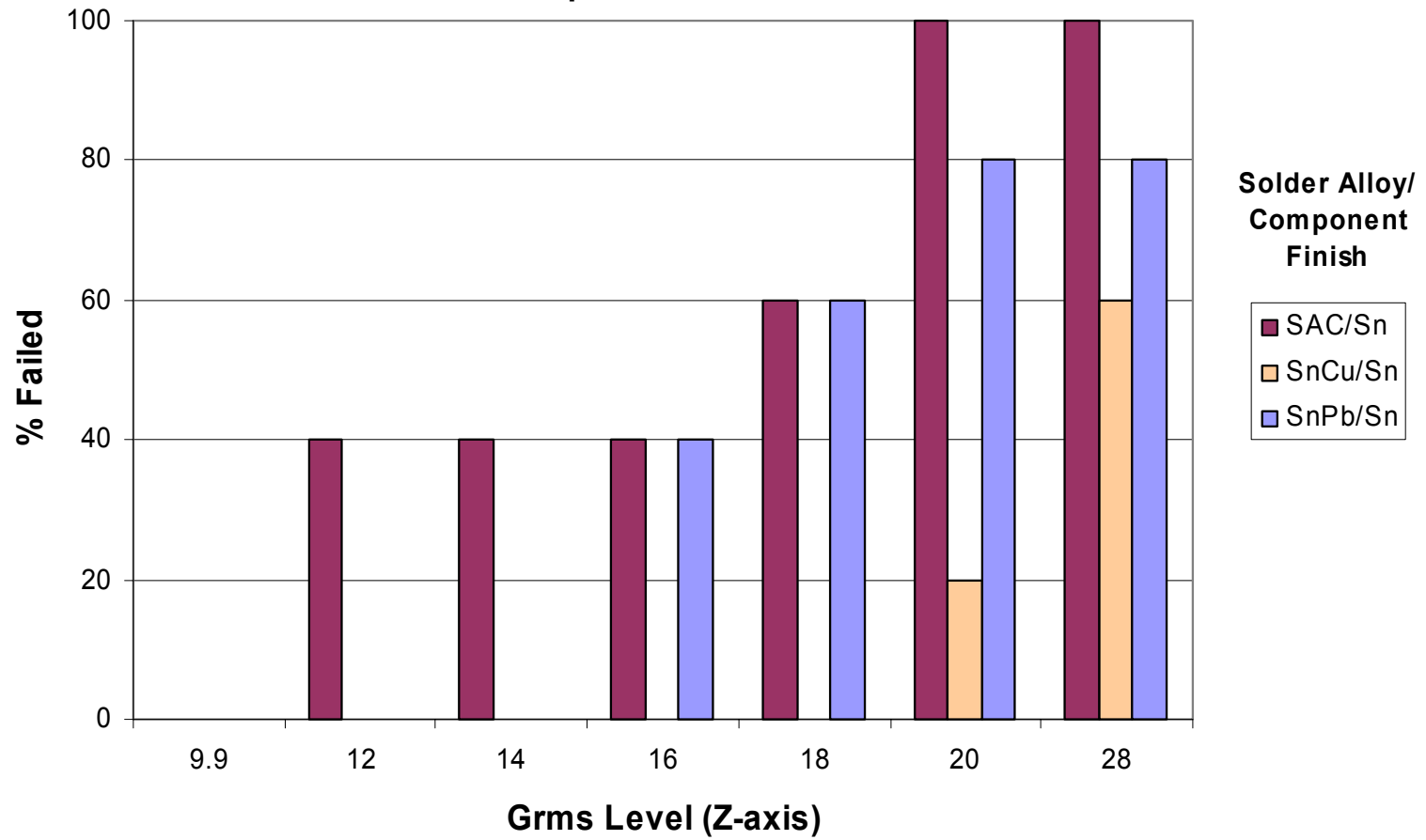
**"Manufactured" Test Vehicles
PLCC-20
Component Location U15**



**"Manufactured" Test Vehicles
PDIP-20
Component Location U35**



"Manufactured" Test Vehicles
PDIP-20
Component Location U51



Preliminary Conclusions

(“Manufactured” Test Vehicles)

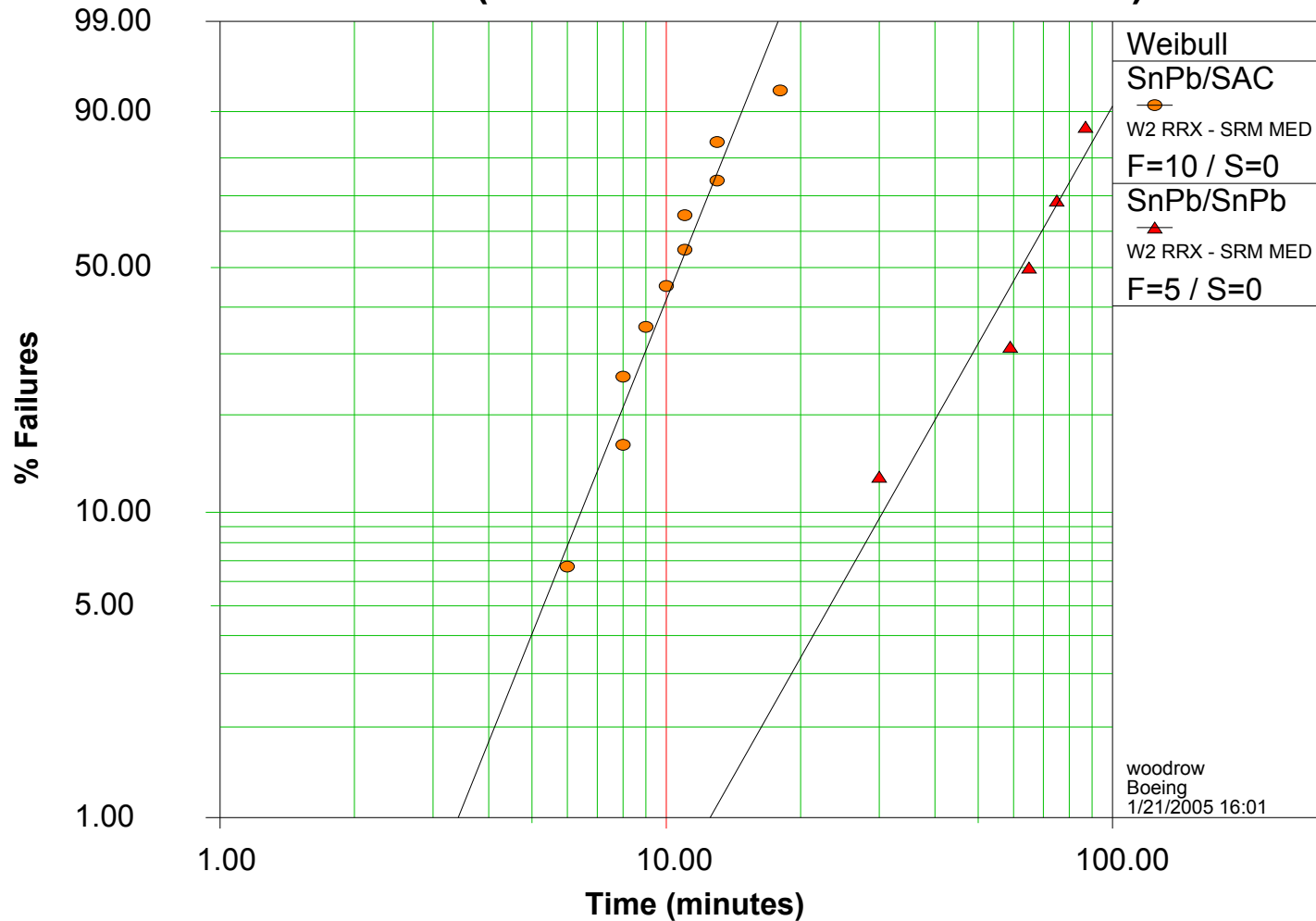
- SnAgCuBi and SnCu(Ni) generally performed well compared to SnPb. SAC did not.
 - ➔ **CLCC's**: SACB = SnPb > SAC
 - ➔ **PDIP's** (Sn Finish): SnCu(Ni) > SnPb > SAC
 - ➔ **PDIP's** (NiPdAu Finish): SnCu(Ni) > SAC > SnPb
- SnPb outperformed the lead-free solders with:
 - ➔ **BGA's**: SnPb solder/SnPb BGA balls always outperformed lead-free solder/SAC BGA balls.
 - ➔ **BGA's**: SnPb solder/SnPb BGA balls always outperformed SnPb solder/SAC BGA balls and lead-free solder/SnPb BGA balls.
 - ➔ **PLCC's** (Sn Finish): SnPb > SACB > SAC
- With TSOP's, the ranking of the solders changed with TSOP orientation.

Extra Slides

Typical Weibull Plot of BGA Data (SnPb Solder Paste/SAC Ball Alloy) vs. (SnPb Solder Paste/SnPb Ball Alloy)

ReliaSoft's Weibull++ 6.0 - www.Weibull.com

BGA U5 (Rework PWA's - Not Reworked)

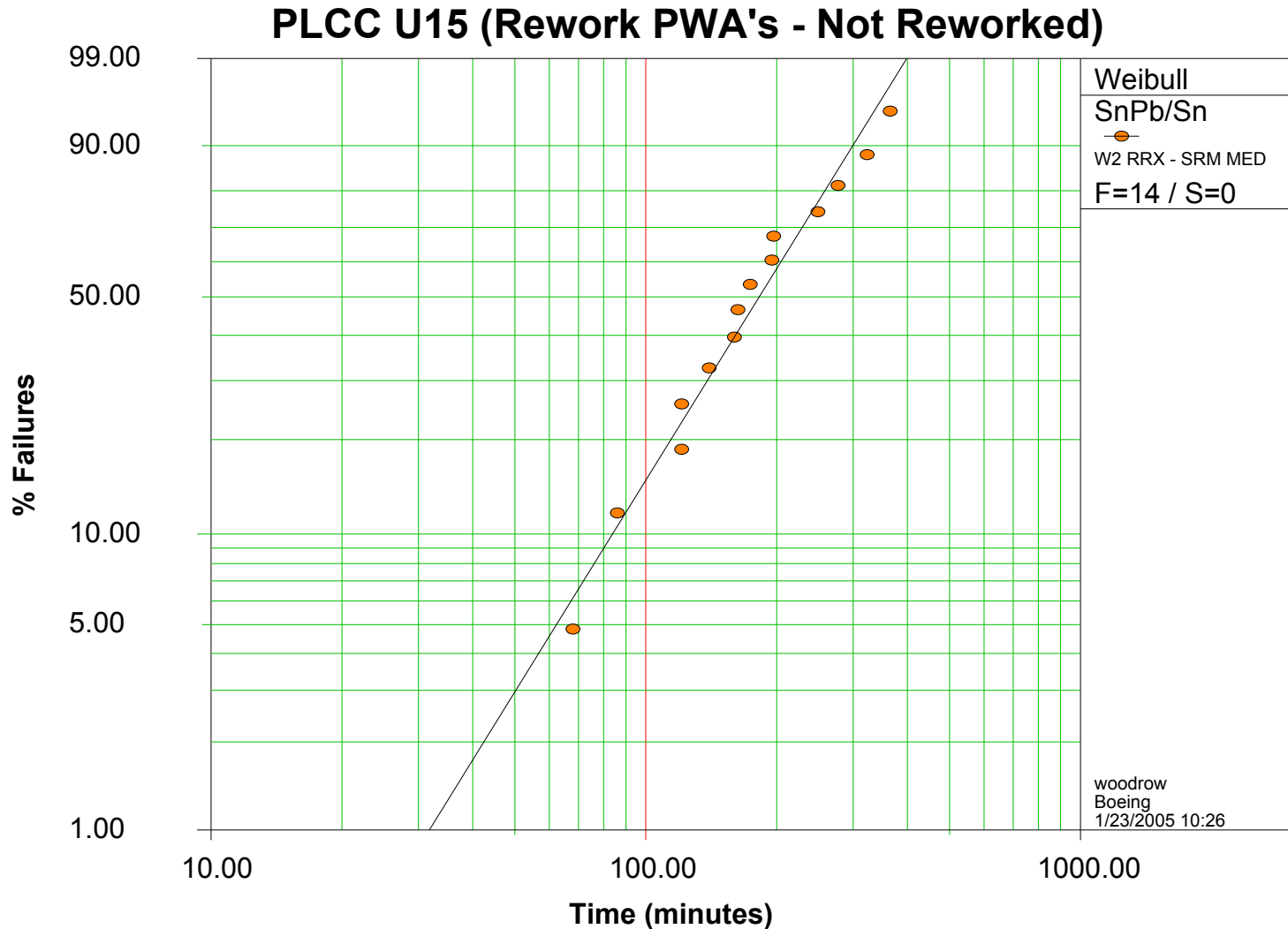


$\beta_1=3.7116$, $\eta_1=11.7971$, $\rho=0.9709$
 $\beta_2=2.6366$, $\eta_2=71.7820$, $\rho=0.9596$

Key: Solder Alloy/Component Finish

Typical Weibull Plot of PLCC Data (SnPb Solder Paste/Sn Component Finish)

ReliaSoft's Weibull++ 6.0 - www.Weibull.com



$\beta=2.4231$, $\eta=212.2001$, $\rho=0.9870$

Key: Solder Alloy/Component Finish